white rose

WHITE ROSE OILFIELD

COMPREHENSIVE STUDY

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Husky Oil

This Comprehensive Study is submitted by Husky Oil Operations Limited (as Operator) on behalf of itself and its co-venturer Petro-Canada, who are the project proponents. The Comprehensive Study is comprised of:

- Introduction
- Project Description
- Part One - Environmental Impact Statement
  - Introduction
  - Regional Setting (Physical Environment)
  - Regional Setting (Biological Environment)
  - Effects Assessment
  - Oil Spills
  - Mitigation Measures and Contingency Planning
  - Monitoring and Reporting
  - Environmental Management
  - References
- Part Two - Socio-Economic Impact Statement
  - Introduction
  - Assessment Scope and Methodology
  - Economic and Demographic Context
  - Business and Employment
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PETRO-CANADA

Husky Oil

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1 INTRODUCTION

This document, combined with the Environmental Impact Statement (EIS) (Part One) and Socio-Economic Impact Statement (SEIS) (Part Two), addresses environmental and socio-economic assessment requirements for the proposed White Rose oilfield development within a Comprehensive Study framework under the *Canadian Environmental Assessment Act* (CEAA).

External to the CEAA process, the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) will also assess the project under the *Atlantic Accord Implementation Act*. This will also involve the evaluation and public review of a Development Application, to be submitted by the proponents in the near future, which will include a Canada-Newfounfland Benefits Plan and Development Plan describing the mode of development and technical operational aspects of the project,

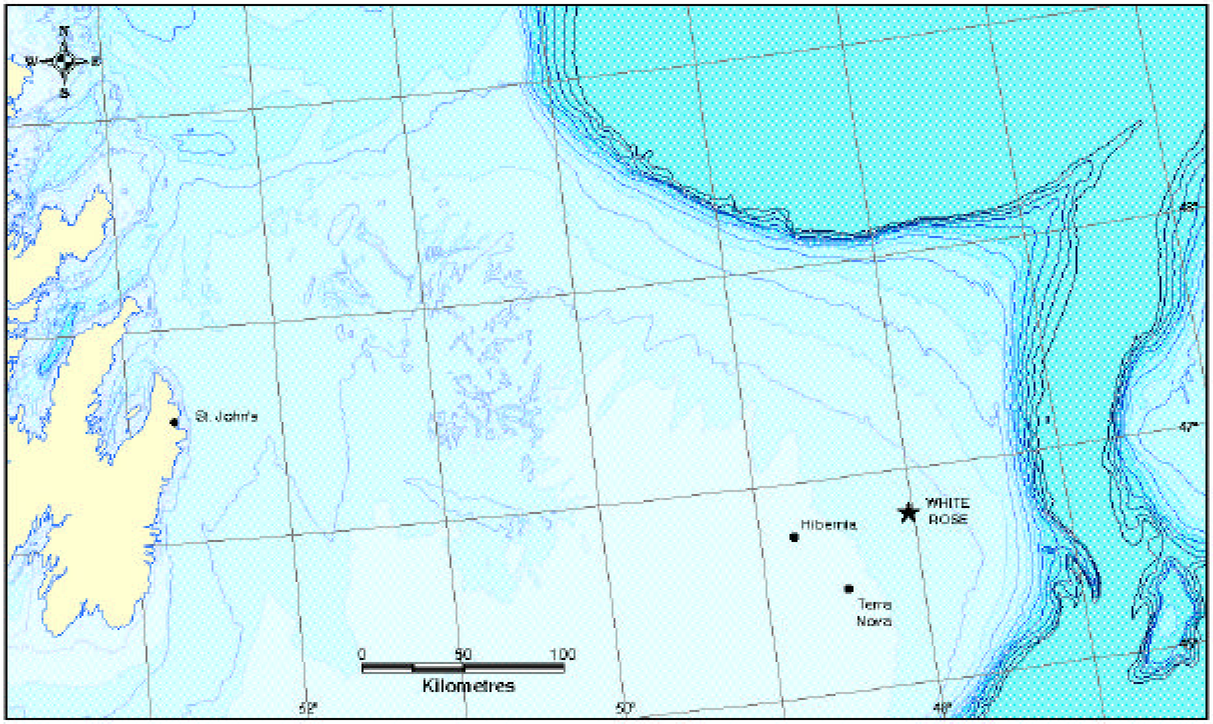
1.1 REGULATORY CONTEXT

Husky Oil Operations Limited (Husky Oil) and its co-venturer Petro-Canada are seeking the appropriate regulatory approvals for the White Rose oilfield development project. The project is located on the Grand Banks offshore Newfoundland approximately 350 km east of St. John's (Figure 1.1-1).

The White Rose project is subject to CEAA. C-NOPB must issue a production licence respecting the project, and thereby performs a duty relating to "the administration of federal lands and …disposes of those lands or any interest in those lands…for the purpose of enabling the project to be carried out" within the meaning of paragraph 5(1)(c) of CEAA. The C-NOPB therefore requires an environmental assessment under CEAA, and is a "Responsible Authority" respecting the project.

The Department of Fisheries and Oceans (DFO) has determined that the project will result in the harmful alteration, disruption or destruction of fish habitat and therefore requires an Authorization for Works or Undertakings Affecting Fish Habitat under Section 35(2) of the *Fisheries Act*. As Section 35(2) authorization requirement is a Law List trigger under CEAA, DFO is also a Responsible Authority with respect to the environmental assessment of the project. Further, as a condition of this authorization, Husky Oil will be required to develop a fish habitat compensation plan that will be used by DFO in the development of a compensation agreement to compensate for losses of productive fish habitat in accordance with DFO's Policy for the Management of Fish Habitat.

Figure 1.1–1 White Rose Location Map



Similarly, Environment Canada (EC) has determined that the construction of glory holes during the project and the deposition of spoils upon the surrounding seabed likely will require a Disposal at Sea Permit under the *Canadian Environmental Protection Act*, and that EC is a Responsible Authority. Finally, Industry Canada (IC) has determined that the radio equipment on the production installation will require its approval pursuant to Section 5(1)(f) on the *Radiocommunications Act*, and that it therefore also is a Responsible Authority respecting the proposed project. The project is subject to a "comprehensive study" level of assessment under CEAA since it falls within the *Comprehensive Study List Regulations*, Part IV, Oil and Gas Projects, Section 11. The C-NOPB is the lead Responsible Authority respecting the assessment, and in that role, is responsible for coordinating the review activities of the other responsible authorities as well as those of other expert government departments and agencies that participate in the review.

The EIS (Part One), in combination with the SEIS (Part Two), form the basis for a Comprehensive Study Report to be submitted to the Minister of the Environment by C-NOPB, DFO, EC, and IC.

1.2 SCOPE OF THE PROJECT

Husky Oil submitted a project description to C-NOPB on March 21, 2000, indicating its intention to submit an environmental assessment and initiate public scoping sessions (Husky Oil 2000). On July 21 2000, C-NOPB, DFO, EC, and IC provided Husky Oil with a scoping document to assist in the preparation of the Comprehensive Study Report (Appendix 1.A). A Table of Concordance with the scoping document is provided in Table 1.2-1.

Table 1.2–1 Table of Concordance with the Scoping Document for the White Rose Oilfield Environmental Assessment

FACTORS TO BE CONSIDERED	SECTION(S) WHERE ADDRESSED
General	
The purpose of the project	Comp. Study, Section 1.3
The need for the project	Comp. Study, Section 1.3
Alternatives to the project	Comp. Study, Section 1.3
Alternative means of carrying out the project which are technically and economically feasible (and the environmental effects of any such alternatives)	Comp. Study, Section 1.4
Environmental assessment methodology	Part One, Section 4.2 Part Two, Section 2.2
Identification of testable hypotheses	Part One, Sections 4.3.5, 5.9.3, 7.1, 8.11
The environmental effects of the project (including those due to malfunctions or accidents)	Part One, Chapters 4, 5 Part Two, Chapters 3, 4, 5, 6, 7 (Integrated throughout Parts One and Two)
Cumulative environmental effects	Part One, Sections 4.2.5, 4.3.4, 4.4.4, 4.5.4, 4.6, 5.9.2.5 Part Two, Sections 2.2, 4.3, 5.2, 5.3, 5.4, 5.5, 5.6, 6.2, 6.3, 6.4, 7.2.2 (Integrated throughout Parts One and Two)
The significance of the environmental effects of the project (including significant criteria)	Part One, Sections 4.2, 4.3, 4.4, 4.5, 4.6, 5.9 Part Two, Sections 2.2, 4.3, 5.2, 5.3, 5.4, 5.5, 5.6, 6.2, 6.3, 6.4, 7.2, 7.3
Measures to mitigate any significant adverse effects (including contingency and compensation measures)	Part One, Chapters 4, 5
The significance of any adverse environmental effects following mitigation (including the feasibility of additional or augmented mitigative measures)	Part One, Sections 4.3, 4.4, 4.5, 4.6, 4.7, 5.9, Chapter 6 Part Two, Sections 4.4, 5.2.3, 5.3.3, 5.4.3, 5.5.3, 5.6.3, 6.2.3, 6.3.3, 6.4.3, 7.3
The capacity of renewable resources that are likely to be significantly affected to meet present and future needs	Part One, Section 5.8 Part Two, Chapter 7
The need for, and requirements of, any follow-up programs	Part One, Sections 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11, 8.12, Chapter 7 Part Two, Sections 4.4, 5.2.3, 5.3.3, 5.4.3, 5.5.3, 5.6.3, 6.2.3, 6.3.3, 6.4.3, 7.3.2
Comments from the public	Comp. Study, Section 1.5 Part One, Section 4.2.1 Part Two, Section 2.2.1 JWEL (2000)
Address factors included in appropriate sections of the C-NOPB *Development Application Guidelines* (1988)	Comp. Study, Section 1.5 Part One, Section 4.2.1 Part Two, Section 2.2.1
Address issues and concerns identified through regulatory, stakeholder and public consultation	Comp. Study, Section 1.5 Part One, Section 4.2.1 Part Two, Section 2.2.1 JWEL (2000)

FACTORS TO BE CONSIDERED	SECTION(S) WHERE ADDRESSED
Definitions of identified VECs (including components or subsets thereof) and the rationale for their selection	Part One, Section 4.2.2 Part Two, Section 2.2.2
The spatial and temporal boundaries of the environmental assessment	Part One, Section 4.2.3 Part Two, Section 2.1
The cumulative effects of the project in combination with other projects or activities, including: • fishing activities; • (for marine birds) hunting activities; • marine transportation activities; • the Hibernia project; • the Terra Nova project; and • petroleum exploration activity.	Comp. Study, Section 1.8 Part One, Sections 4.2.5, 4.3.4, 4.4.4, 4.5.4, 4.6, 5.9.2.5 Part Two, Sections 2.2, 4.3, 5.2, 5.3, 5.4, 5.5, 5.6, 6.2, 6.3, 6.4, 7.2.2 (Integrated throughout Parts One and Two)
Significance criteria for evaluating adverse environmental effects	Part One, Sections 4.2.4, 4.2.6 Part Two, Section 2.2
Air Quality	
Air emissions (including annual estimates)	Part One, Sections 4.3.1.16, 4.3.2.13, 4.4.1.5, 4.4.2.6, 8.8.3.1
Health and safety implications of air emissions	Part One, Appendix 4.A
"Greenhouse gas" emissions (including annual estimates and means for their reporting and reduction)	Part One, Sections 4.3.1.16, 4.3.2.13, 8.8.3.1, Appendix 8.A
Marine Resources	
The seabed area predicted to be affected by dredging, trenching and dredge spoil disposal, drill cuttings and other discharges	Part One, Sections 4.2.1.1, 4.3.1, 4.3.2
Quantification of the spatial area of affected seabed	Part One, Section 4.3.1.3
Marine/Migratory Birds	
Species distributions (spatial and temporal)	Part One, Sections 3.1.4, 3.9
Species habitat, feeding, breeding and migration	Part One, Section 3.9
Particularly sensitive (i.e., threatened / endangered) bird species	Part One, Section 3.9.4.4
Potential attraction of birds	Part One, Section 4.4
Potential for bioaccumulation of heavy metals associated with project discharges by birds	Part One, Section 4.4
Effects of aircraft overflights on bird concentrations and/or colonies	Part One, Sections 4.4.1.7, 4.4.2.8
Effects of oil spills on birds, as well as any sheens that may be associated with regulated discharges	Part One, Sections 4.4.1, 4.4.2, 4.4.3, 4.4.4, 5.9.2.2
Means for assessing and documenting any bird mortalities	Part One, Section 7.1.2
Design and/or operational procedures for mitigating effects to birds	Part One, Section 4.4, Chapters 6, 8
Marine Fish, Shellfish, Reptiles and Marine Mammals and Their Respective Benthic and Water-Column Habitat	
Existing conditions in the project area, affected area and region (including species distribution and abundance, life stages)	Part One, Chapters 2, 3
Location, type, diversity and extent of marine fish habitat in the project and affected areas (particularly those supporting fishing activity and including any critical habitats)	Part One, Chapters 3, 4 Part Two, Chapter 7
Environmental (including cumulative) effects (considering lethal and sublethal effects, species interrelationships, fish health, productivity, and affected habitat)	Part One, Sections 4.3, 4.5, 5.9, 7.2
Marine Use	
Size and location of exclusion zones	Comp. Study, Section 1.2 Part One, Section 4.3 Part Two, Section 7.2
Project-related traffic (including routings, volumes, schedules, and vessel types)	Comp. Study, Section 1.2.1 Part One, Sections 4.3, 4.4, 4.5 Part Two, Sections 7.2, 7.3
Effects on access to fishing grounds	Part Two, Sections 7.2, 7.3
Effects on marine traffic/navigation (including research surveys)	Part Two, Sections 7.2, 7.3
Traditional, existing and potential commercial, recreational and Aboriginal/subsistence including foreign fisheries (including underused species, species under moratoria and the traditional and changing nature of the fishery)	Part One, Section 3.8 Part Two, Chapter 7
Effects of project operations and accidental events on current and	Part Two, Sections 7.2, 7.3

FACTORS TO BE CONSIDERED	SECTION(S) WHERE ADDRESSED
potential fisheries	
Effects of real/perceived shellfish taint	Part One, Sections 4.3, 5.9.2 Part Two, Sections 7.2, 7.3
Cumulative effects to fisheries	Part Two, Section 7.2.2
Discharges and Emissions	
Effects of electromagnetic emissions from radio equipment on personnel safety and mitigation/elimination measures	Part One , Section 8.8.3.6
Planned project discharges to the marine environment (including dredge spoil, drilling fluids and cuttings, produced water, bilge water, "grey" and "black" water, cooling water, deck drainage)	Comp. Study, Section 1.2.1 Part One, Sections 4.3, 4.4, 4.5
Characterization, quantification and modelling of expected discharges (including a description of models employed)	Comp. Study, Section 1.2.1 Part One , Sections 4.3.1.4, 4.3.2.5 Hodgins and Hodgins (2000)
Means for the reduction, reuse and recovery of wastes	Comp. Study, Section 1.2.1 Part One, Sections 4.3.1, 4.3.2, 8.8.3
Feasibility of subsurface re-injection of produced water and drill cuttings associated with organic-phase drilling fluids	Part One, Section 4.3.1.4, 4.3.2.5
Accidental Events	
Quantification of blowout risk	Part One, Sections 5.2, 5.7
Quantification of risk of oil spills of all volumes	Part One, Sections 5.3, 5.4, 5.5, 5.6, 5.7
Modelled physical fate of oil spills (including models, analyses and data)	Part One, Sections 5.8, 6.10
Environmental effects of oil or chemical spills	Part One, Sections 4.3, 4.4, 4.5, 5.9 Part Two, Sections 7.2, 7.3
Cumulative effects of "chronic" oil pollution on the Grand Banks	Part One, Sections 4.3.4, 4.4.2, 4.4.4, 4.5.4, 5.9.2
Effectiveness of spill countermeasures	Part One, Section 6.10, Chapter 8
Physical Environment	
Meteorological, oceanographic and seabed conditions (including extreme conditions)	Part One, Chapter 2
Sea ice and iceberg conditions (including iceberg scour)	Part One, Sections 2.5, 2.6.3
Physical environment monitoring, observation and forecasting programs	Part One, Section 2.5.4, Chapter 6
Ice management/mitigation procedures (including criteria for disconnection and an assessment of the efficiency of detection/deflection techniques)	Comp. Study, Section 1.7 Part One, Section 2.5.4, Chapter 6
Environmental Management	
Proponent's/Project environmental management system	Part One, Chapter 8
Pollution prevention policies and procedures	Part One, Section 6.10, Chapter 8
Environmental effects monitoring programs	Part One, Sections 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11, Chapter 7 Part Two, Section 7.3.2
Environmental compliance monitoring	Part One, Section 8.12
Provisions for management system auditing	Part One, Section 8.8
Environmental training for employees and contractors	Part One, Section 8.2.5
Chemical selection and management procedures	Part One, Section 4.3.1.4
Fisheries liaison/interaction policies and procedures	Part One, Sections 8.8, 8.14 Part Two, Section 7.3
Program(s) for compensation of affected parties for accidental damage	Part One, Sections 4.3.4, 8.14 Part Two, Sections 7.2, 7.3
Fish habitat compensation strategy and options	Part One, Sections 4.3, 7.2
Emergency response plans	Part One, Chapter 6
Environmental Effects Monitoring (EEM)	
Characteristics of EEM programs for routine and accidental events (including their design process)	Part One, Sections 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11, Chapter 7 Part Two, Section 7.3.2
Parameters to be monitored and the rationale for their choice	Part One, Sections 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11,

FACTORS TO BE CONSIDERED	SECTION(S) WHERE ADDRESSED
(including consideration of marine birds, reptiles and mammals, fisheries, fish and shellfish health/productivity and taint, fish habitat, and marine environmental quality)	Chapter 7 Part Two, Section 7.3.2
Linking of monitoring hypotheses to testable hypotheses	Part One, Section 7.1
Site-specific baseline information	Comp. Study, Appendix 1.B Part One, Section 7.6
Integration into a regional EEM program	Part One, Section 7.3
Distinction of "signal" from "noise" in monitoring programs	Part One, Section 4.3.5
Independent/peer review of monitoring results	Part One, Section 7.6
Linkage of monitoring results into environmental management system	Part One, Sections 7.1, 8.11
Potential requirements for fish habitat compensation and post-dredging monitoring	Part One, Sections 4.3.1.3, 7.2 Part Two, Section 7.3.2
Abandonment/Decommissioning	
Plans for abandonment/decommissioning of the project area following termination of production, including any requirements for post-abandonment monitoring	Part One, Sections 4.3.3, 4.4.3, 4.5.3, Chapter 7 Part Two, Chapter 13

The scope of the project, as identified in that scoping document includes:

- construction, installation, operation, maintenance, modification, decommissioning and abandonment of a petroleum production facility respecting the White Rose oilfield, as described in the White Rose Oilfield Project Description prepared by Husky Oil and dated March 17, 2000;
- construction, installation, operation, maintenance, modification, decommissioning and abandonment of subsea facilities associated with the White Rose field, including drilling and workover of development wells, subsea flow lines and any related excavation of the seabed and associated spoil deposition;
- operation of support craft associated with the above facilities, including but not limited to mobile offshore drilling units, platform supply and standby vessels and helicopters, and shuttle tanker activity that is incremental to that already in existence or expected to be in existence; and
- any new onshore facilities that are expected to be required to support the above activities.

The following summarizes the Project Description as submitted to the C-NOPB.

The White Rose oilfield development is anticipated to recover an estimated 36 million m^3 (230 million barrels) of recoverable oil from an area of approximate 40 km^2 in the Jeanne d'Arc Basin. A ship-shaped floating, production, storage and offloading (FPSO) facility, similar to that selected for Terra Nova, will be used to develop the oilfield. This ship-shaped facility will be able to store between 700,000 and 850,000 barrels of oil (approximately 8 to 10 days of oil production) and will contain topside processing units, accommodations and a turret to facilitate the positioning and emergency response of the vessel.

There will be three to four drill centres on the seafloor, with production and water and gas injection wells located at each centre. These drill centres will be located in three to four excavated glory holes that lie below the seabed to protect the wells from iceberg scour. The drill centres will be connected to the FPSO facility with flexible flowlines and risers. The FPSO's turret is designed to allow the facility to disconnect from the subsea drill centres and move location in the event of an emergency.

Developing the White Rose oilfield will require drilling up to 10 to 14 production wells in the South White Rose reservoir. The production from the combined wells is estimated between 12,000 to 18,000 m^3 (75,000 and 110,000 barrels) of oil daily. An additional 8 to 11 water and gas injection wells will be drilled to maintain the reservoir pressure and for resource conservation. The wells will be drilled in phases over a four to six year period. Four to six production wells, one to three water injection wells and one gas injection well will be required for First Oil production. The project has an estimated life span of 12 to 14 years (Husky Oil 2000).

Both seawater and, if necessary, produced gas will be used for maintaining reservoir pressure. Seawater will be treated and then injected into the reservoir. Produced gas will be reinjected for resource conservation and, if necessary, reservoir pressure maintenance and conservation. There is no intention to flare produced gas, except for specific and limited operational, maintenance or safety requirements.

No new on-shore facilities are expected to be required to support the above activities. All on-shore construction and fabrication activities are expected to be carried out at existing industrial sites.

1.2.1 Shuttle Tanker Activity

Shuttle tanker activity that is incremental to that already in existence or expected to be in existence is assessed in this EIS. The interaction with the Valued Environmental Components (VECs), and effects of that interaction are considered. Husky Oil has not determined the ultimate destination of its crude. Shuttle tankers will be used for exporting White Rose crude to markets in Eastern North America, the U.S. Gulf Coast, other international destinations or to a transshipment facility, such as the one currently operating at Whiffen Head, Newfoundland. Depending on the distance to market and on the volumes of crude to be exported, one to three tankers will be required. They will be ice-strengthened and double hulled, and sized appropriately for the transportation requirements.

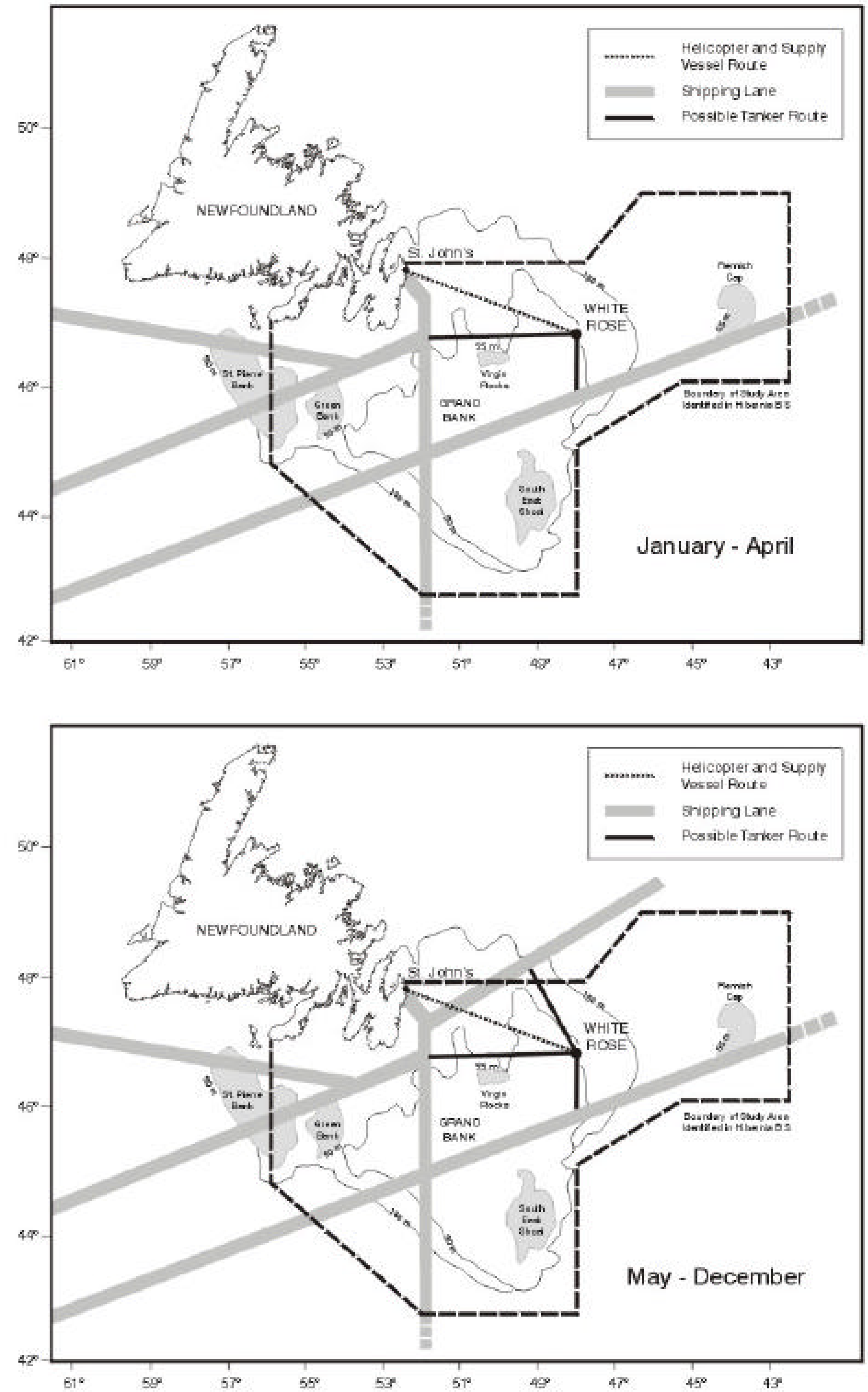
The boundary for assessing the effects of the incremental shuttle tanker traffic coincides with the designated transportation routes on the Grand Banks up to the point where they meet the international shipping lanes. These routes to the major shipping lanes are shown in Figure 1.2-1. All vessels using shipping lanes in Canadian waters must comply with the *Canada Shipping Act*, as well as with international conventions such as the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Convention on Oil Preparedness Response and Cooperation (OPRC). Mariners transporting White Rose crude will be contractually bound to follow all applicable Canadian legislation and international conventions.

MARPOL is an international agreement that aims to control pollution from ships, eliminate pollution of the sea due to operational discharges of oil, chemicals and other harmful substances, and minimize accidental releases of oil from ships and offshore platforms (fixed or floating). MARPOL requires parties to adopt design, construction and operation standards for ships and their equipment, and port facilities. The *Canada Shipping Act* and its regulations reflect the requirements of MARPOL.

The Newfoundland Transshipment facility was assessed pursuant to the federal CEAA and the provincial Newfoundland and Labrador *Environment Assessment Act* (NTL 1996). The project was released from the provincial process in December 1996 and from the requirements of CEAA in January 1997. The scope of the project assessment included tankage for the Hibernia crude and additional tanks to accommodate product from other fields.

The Canadian Coast Guard (CCG) coordinates the Technical Review Process of Marine Terminal Systems and Transshipment Sites (TERMPOL). This non-regulatory process assists the CCG in determining the need for making or revising specific regulations, or need for implementing special precautionary measures that may affect a ship's operation within a particular marine terminal system or transshipment site (CCG, no date). As a supporting exercise to the TERMPOL review process of the Newfoundland Transshipment facility, NTL was required to assess the environmental effects of an oil spill along the designated shipping route in Placentia Bay. This assessment focused on potential oil spills originating from NTL-related vessels and possible spills from other oil-carrying vessels due to an accident involving an NTL-related vessel (JWEL 1997). That assessment was conducted using methodology consistent with CEAA (CEAA 1994a). The volume of traffic assessed included 100 Hibernia tanker movements a year and up to 200 additional tanker movements a year for the other offshore oil developments anticipated as of 1996. Therefore, the effects of incremental tanker traffic into and out of Placentia Bay have been assessed, and will not be further addressed in this document.

Figure 1.2–1 Transportation Routes Relevant to White Rose



1401-67.cdr 26JUN00 Figure 4.4-1

Source: adapted from Mobil (1985)

1.2.2 Spatial Boundaries

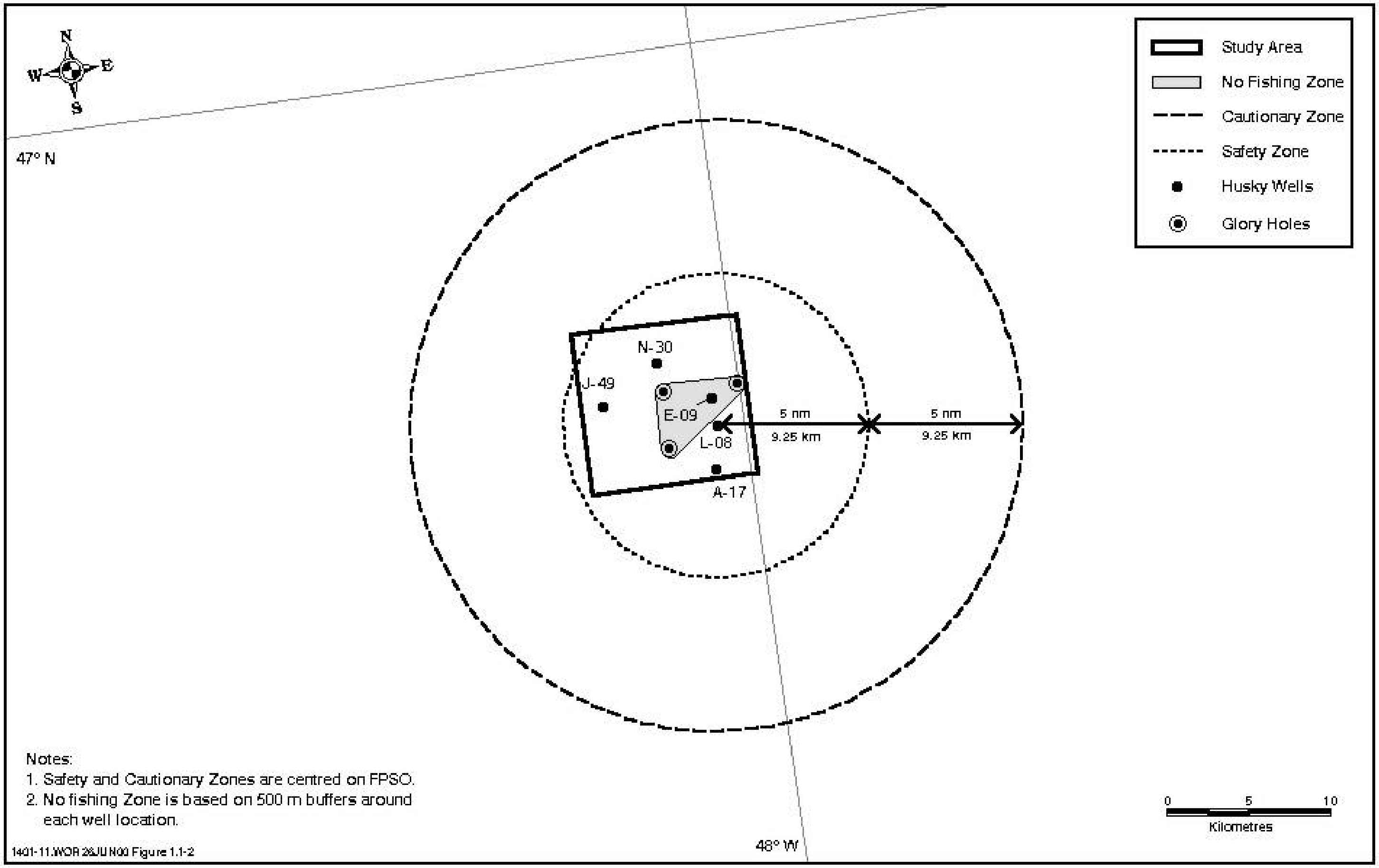
Several different spatial boundaries are used in this environmental assessment. The project area, that area directly disturbed by construction, installation, operation and related activities, including physical works (that is, locations of glory holes, production facility moorings, drilling unit moorings and subsea flowlines and any vessel and/or fishery exclusion zones is depicted in Figure 1.2-2. This proposed White Rose safety zone, including a no fishing area, is approximately 5 nautical miles in diameter.

The affected area, or area that could potentially be affected by project activities beyond the project area, has been determined using comprehensive models of drill cuttings and produced water discharges. These potentially affected areas, or zones of influence, for drill cuttings and produced waters are depicted in Figures 4.3-2 and 4.3-3 to 4.3-4, respectively of the EIS (Part One) and described in detail in Sections 4.3.1.4 and 4.3.2.5, respectively of the EIS (Part One). For accidental events, areas potentially affected were determined through oil spill modelling (Chapter 5 of the EIS (Part One)).

The Regional study area boundary area extending beyond the "affected" area, is considered to be the Grand Banks ecosystem, as defined in the Hibernia EIS (Mobil 1985) and the Terra Nova Development EIS (Petro-Canada 1995). This regional study area is depicted in Figure 3-1 of the EIS (Part One) and its physical environment characteristics are described in Chapter 2 of the EIS (Part One)and its biological environment characteristics are described in Chapter 3 of the EIS (Part One).

In addition, for each Valued Environmental Component (VEC), there is a defined study area specific to their own individual characteristics, both for the biophysical and socio-economic VECs. The fish and fish habitat study area is depicted in Figure 3.8-1 of the EIS (Part One) and the marine birds, marine mammals and sea turtle study area is depicted in Figure 3.9-2 of the EIS (Part One). The study area for the commercial fisheries VEC is depicted in Figure 7.1-2 of the SEIS (Part Two).

Figure 1.2–2 White Rose Project Area: No Fishing Zone and Safety Zone



1.3 NEED, PURPOSE AND ALTERNATIVES TO THE PROJECT

Husky Oil and Petro-Canada propose to develop a significant oil discovery in the White Rose area. Husky Oil and Petro-Canada believe that this project will meet international market demands for oil and generate considerable economic benefits for the economies of Newfoundland and Labrador and Canada, as well as provide a reasonable financial return for Husky Oil and Petro-Canada. The development will increase employment opportunities for people of the province and will contribute to the growth in petroleum industry infrastructure and business opportunities arising from the increased demand for necessary goods and services. This will ultimately attract new investment to the province, contributing to the sustained growth of the provincial and Canadian economies. From Husky Oil's perspective, the need for the proposed development is to satisfy its goal to acquire, find and develop substantial oil reserves. This will have a major impact on the company's overall growth and be in keeping with its mission statement: "to maximize returns to its shareholders in a socially responsible way".

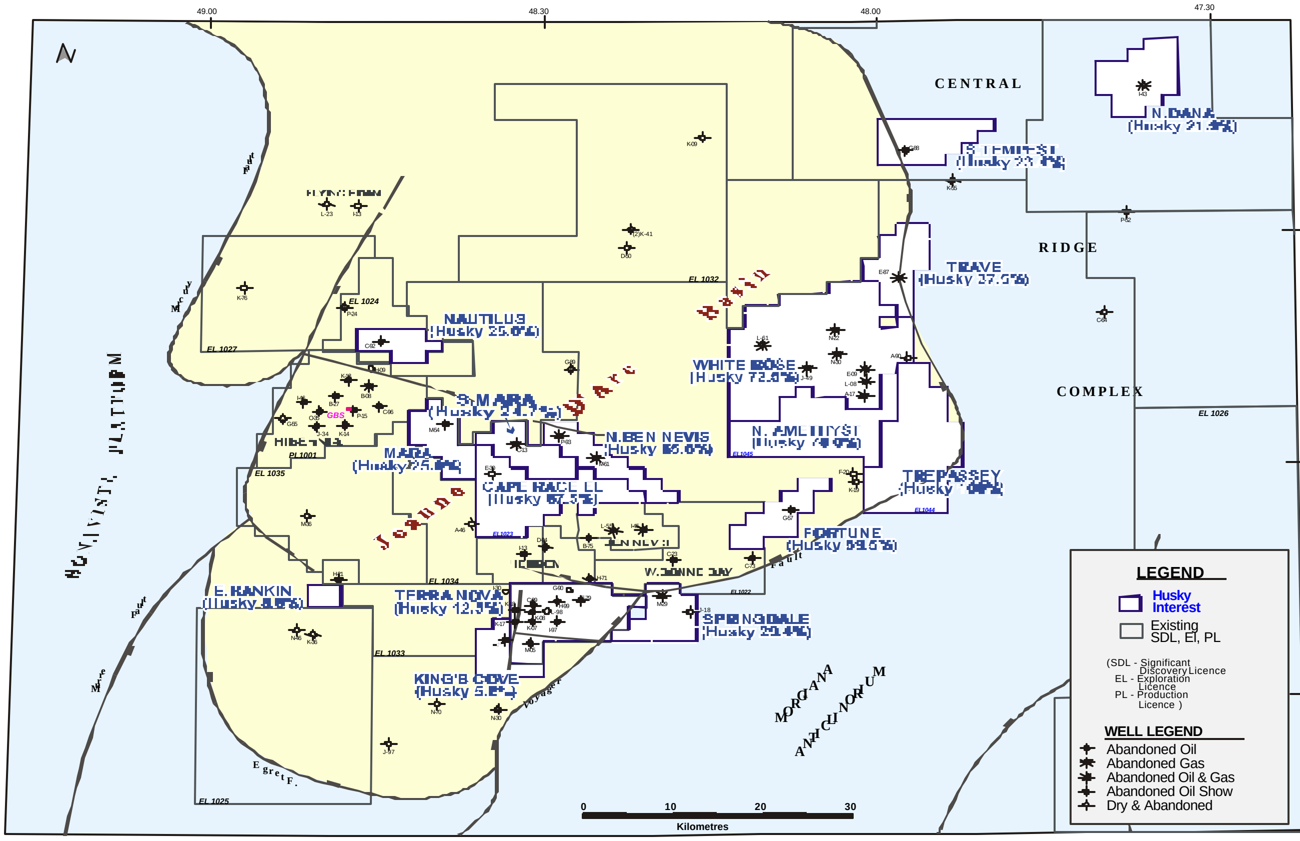
Husky Oil is one of the leading operators and interest holders in the Canadian East Coast offshore oil industry. Husky Oil's land holdings (Significant Discovery Areas and Licenses) in the Jeanne d'Arc Basin are indicated in Figure 1.3-1. The current land holdings are the result of significant investment, an extensive exploration program initiated in 1982, and a series of inter-company and land sale acquisitions over the past 18 years. Husky Oil holds an approximate 32 percent net working interest in the Significant Discovery Licence areas in the Jeanne d'Arc Basin. Petro-Canada is the operator of the Terra Nova oilfield and also holds substantial interests in the Newfoundland offshore region. The Jeanne d'Arc sedimentary basin is recognized as the principal oil-producing basin off the East Coast of North America. It is a significant business area for Husky Oil and a key to the company's continued growth.

Several alternatives for servicing the market demand for energy include development of other energy projects, such as hydroelectric, nuclear power and co-generation. An additional alternative would be for consumers to reduce their requirement for energy. Given the present circumstances in the Province of Newfoundland and Labrador, including the existence of already developed infrastructure to support offshore oil and gas development, and the present state of knowledge with respect to the recoverable resources, the proposed White Rose oilfield development is an appropriate vehicle through which to help meet overall market demands for energy.

An alternative to Husky Oil's goal of meeting the market demands for oil at an acceptable financial return is for it to proceed with alternative projects, in another of the company's core asset areas. However, market conditions, and the development of infrastructure to support the Newfoundland offshore industry, favour Husky Oil investing in the White Rose oilfield development. Husky Oil has undertaken engineering and economic analyses of the White Rose oilfield development to determine that it is technically, economically and environmentally feasible.

Figure 1.3–1 Current Husky Land Holdings and Working Interests in the Jeanne d'Arc Basin

Jeanne d'Arc Basin
HUSKY WORKING INTERESTS



1.4 ALTERNATIVE MEANS

Eight potential options were identified and considered as alternative means to the White Rose oilfield:

- steel floating FPSO facility;
- concrete FPSO facility;
- steel floating, production, drilling, storage, offloading (FPDSO) facility;
- concrete gravity-base structure (GBS);
- steel semi-submersible facility with and without integral storage;
- concrete semi-submersible facility;
- disconnectable concrete tension leg platform (TLP); and
- concrete barrier wall with floating production unit (FPU).

The evaluation criteria included:

- technical requirements;
- capital costs;
- construction time;
- concept maturity;
- concept deliverability; and
- risk considerations.

A two-stage process was used to evaluate the concepts. The first stage involved qualitative screening whereby options that were either insufficiently developed or clearly failed to satisfy primary technical criteria were identified. As a result of analysis at this stage, the disconnectable concrete TLP, concrete barrier wall with FPU, and steel FPDSO facility were not carried forward as they either did not meet Husky Oil's technical requirements or were prototype development concepts with no operating history in harsh-environment offshore locations.

These remaining five options (steel FPSO facility, concrete FPSO facility, steel semi-submersible facility with and without integral storage, concrete semi-submersible facility, and concrete GBS) were further analyzed with respect to construction time, capital costs, concept maturity, concept deliverability, and risk considerations. The ranking of the five options on the basis of construction costs and time are shown in Figure 1.4-1, while the five options are ranked based on the technical risk associated with each option as illustrated in Figure 1.4-2.

1.4.1 Preferred System

The evaluation of the options concluded that the preferred option for developing the White Rose oilfield was a steel FPSO facility using subsea wells located in glory holes, similar to that selected for the Terra Nova Development. This system was evaluated as top preference on project cost and time to First Oil (Figure 1.4-1).

Figure 1.4–1 Ranking of Five Concepts on the Basis of Construction Costs and Time

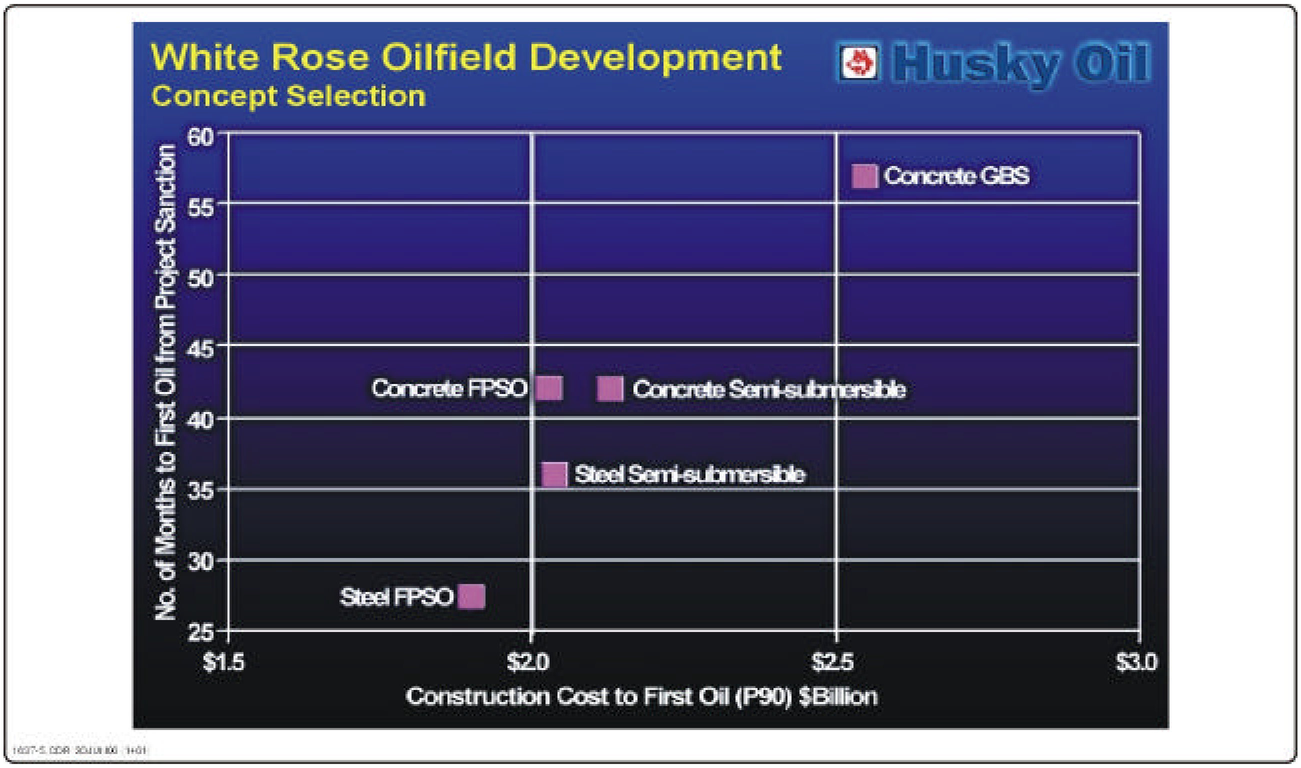
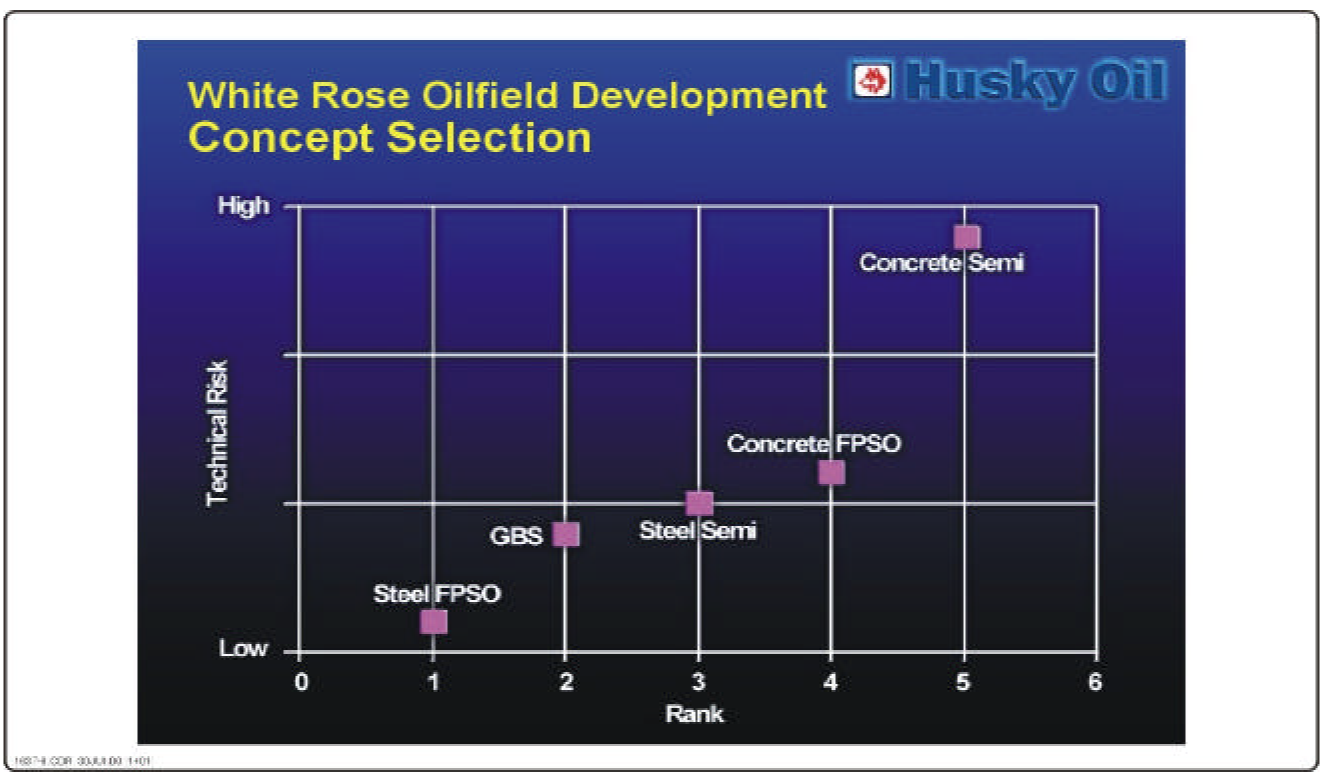


Figure 1.4–2 Ranking of Five Concepts on the Basis of Technical Risk



Key factors contributing to the selection of the steel FPSO facility as the preferred option are:

- It is the most economically viable way to develop the White Rose field, taking into account feasibility, flexibility, deliverability, costs, risk and safety.
- It has the most commercial and technical flexibility. Therefore, it is well suited to a complex field with technical challenges, such as White Rose which is considerably smaller than Terra Nova and Hibernia.
- It has the flexibility to deal with different production and storage levels effectively.
- It has a proven track record in harsh environments, with some 60 FPSO facilities currently in operation or under construction around the world.
- It can produce both oil and gas in sequential development.
- It has the flexibility necessary to tie-in future fields.
- It can be producing at capacity earlier than other production facilities.
- It poses less of a challenge at decommissioning than other production facilities.

1.4.2 Alternative Systems

The physical characteristics of the four alternative systems evaluated are briefly described in the following subsections. Only the semi-submersible with a detached floating storage unit is considered technically and economically feasible.

1.4.2.1 Concrete Floating, Production, Storage and Offloading Facility

This concept consists of a concrete barge outfitted for production, storage and offloading in a similar fashion to a steel FPSO. Due to displacement considerations, its plan area is necessarily larger than the equivalent steel FPSO. It has the ability to disconnect, if required due to extreme conditions or icebergs.

The concrete FPSO option was considered inferior to the steel FPSO option on the basis of feasibility. There are no existing units in the world and the construction scale is so large it would create expensive demands on construction facilities.

A concrete FPSO is marginally more flexible than a steel FPSO because the vessel size has to be large to support its own self-weight, and this size provides additional deck space.

With respect to deliverability, the concrete FPSO was considered inferior to the steel FPSO option because of the likelihood of limited construction facility competition for the concrete hull and the lack of industry experience on the required scale.

This system was evaluated as second preference on project cost and third for time to First Oil (Figure 1.4-1).

1.4.2.2 Steel Semi-Submersible Facility With and Without Integral Storage

The semi-submersible concept consists of a floating hull form with four columns connected by sub-surface pontoons. Production facilities are mounted on the facility deck. The subsea facilities are similar to those for a FPSO facility. The semi-submersible is anchored to the seabed by fixed catenary chain and wire moorings and does not 'weather vane'. The flexible risers are fixed to a porch(s) on the semi-submersible facility's hull. In the event of iceberg threat, the porch(s) could be disconnected, the risers lowered and the unit moved aside using thrusters.

Many of the key technical issues for a steel semi-submersible mirror those for a concrete semi-submersible. This option was assessed as being similar to the concrete semi-submersible in respect of flexibility, but having a higher ranking in respect of feasibility and deliverability. This higher ranking was largely due to considerable operational experience, with almost 40 production units in operation worldwide.

This system was evaluated as third preference on project cost and second on time to First Oil (Figure 1.4-1). A principal reason for selecting the steel FPSO facility over the steel semi-submersible was the forecast life-cycle cost. The steel semi-submersible cost was estimated to be $190 million more than the steel FPSO facility at the production level anticipated. Another disadvantage is the lack of existing engineering for an emergency disconnect system.

1.4.2.3 Concrete Semi-Submersible Facility With and Without Integral Storage

This concept is similar to the steel semi-submersible concept, except the construction material is concrete.

The only concrete semi-submersible in existence is the Troll B structure, installed in 1995 in the Norwegian North Sea. The semi-submersible is a production facility without drilling or storage capabilities. It has a design capacity to produce 27,000 m^3 (170,000 barrels) of oil per day. This structure is very large compared with equivalent steel production units, having a plan area about 40 percent greater, a wave area more than 200 percent greater and a displacement more than 300 percent greater. A concrete semi-submersible unit for White Rose would be smaller than the Troll B, but would still be significantly larger than a steel semi-submersible, leading to significantly higher mooring costs.

One disadvantage of the concrete semi-submersible concept is the lack of an emergency disconnect system. Although feasible, this would take a reasonable amount of design development. Another significant deficiency is the need for an independent means of propulsion in the event an emergency disconnect is required.

This system was evaluated as fourth preference on project cost and third on time to First Oil (Figure 1.4-1).

1.4.2.4 Concrete Gravity Base Structure

The GBS concept evaluated is conceptually similar to that used on the Hibernia field. However, it has an innovative design with the potential for much lower costs that have already been incorporated in Figure 1.4-1. The structure rests on the seabed and is designed to resist the forces imposed by iceberg and other environmental loads. The topside facilities include drilling equipment, as well as the process plant, with all wells drilled and maintained from the platform. Oil is stored within the base structure and offloaded via a subsea pipeline to a loading buoy located a short distance from the GBS.

It is ranked second with the steel FPSO option based on feasibility. However, the proposed design requires significant issues to be resolved before there is sufficient confidence in material quantities. These relate to risk assumptions with respect to the foundation design, where the soil strength is unknown, and local ice pressure loads.

A significant challenge for the concrete GBS is considered to be deliverability, where the concept is ranked lowest of the top five options.

This system was evaluated as last preference on project cost and last on time to First Oil (Figure 1.4-1). It also showed a negative return on investment.

The concrete GBS was ultimately eliminated as an option on the following grounds:

- It is not economically viable for a field the size of White Rose as there are insufficient petroleum reserves established or likely to be established in the field to recover the cost of the GBS.
- Its forecast construction cost is $507 million more than the steel FPSO option.
- It has a forecast negative return on investment.
- Of all options considered, it ranks the most unfavourably with the steel FPSO option based on cost and deliverability.
- Its construction is complex.
- It requires a long lead time.
- It presents substantial problems for decommissioning and abandonment, which would likely become much greater liabilities over time. It is not practical for relocation for further service at another site.

1.4.3 Time to First Oil for Options Considered

The time to First Oil for each of the options considered is shown in Table 1.4-1.

Table 1.4–1 Time to First Oil for Options Considered

Option	Months to First Oil	Wells to First Oil	Ramp-up Period (months)
Steel FPSO	36	10	0
Concrete FPSO	42	10	0
Steel Semi-submersible	36	10	0
Concrete Semi-submersible	42	10	0
Concrete GBS	57	4	12

Except for the GBS, all cases assume up to 10 wells to be pre-drilled to First Oil and a production ramp-up period is not required. For the GBS, it is assumed that one well can be drilled from the GBS before the structure is operational at 48 months. It is further assumed that an additional three wells will be drilled and First Oil will occur at 57 months. It will not be until 12 months later that a total of eight wells will be available on the GBS and full production capacity is achieved. The estimated schedule for the FPSO for White Rose is 36 months from Contract Award to First Oil. This assessment is based upon experience from Terra Nova and benchmarked data for North Sea FPSOs, with due allowance for size and complexity factors. A steel semi-submersible is also tied with the steel FPSO in reaching First Oil in 36 months, while a concrete semi-submersible and concrete FPSO are tied at 42 months to First Oil. An early First Oil date is important in maintaining the financial viability of the White Rose project, which has significant less reserves than the other projects currently on the Grand Banks.

1.4.4 Summary of Feasible Options

The only two development concepts that would be technically and economically feasible were the steel semi-submersible with or without integral storage and a steel FPSO. The development, operations, decommissioning and accidental events for both an FPSO and a semi-submersible are not markedly different with respect to their interaction with the environment. For example, construction activities and disburbance, operational discharges, structural presence, and support activities are very similar for both options. Therefore, the effects predictions for both alternatives on the environment would be the same. The environmental and socio-economic effects of the preferred option are therefore assessed in detail in Parts One and Two.

1.5 ISSUES SCOPING AND STAKEHOLDER CONSULTATION

The focus (or scope) of an environmental assessment must be identified early in the environmental assessment process. The scope of the project to be assessed and the scope of factors to be considered are important for conducting an effective and efficient environmental assessment (CEAA 1998). The components of the environment (interpreted in its broadest sense to include the socio-economic and cultural environment, as well as the biophysical environment) that are valued by society are the recommended focus of an assessment (Beanlands and Duinker 1983). These components are called VECs.

Issues scoping is the process used to focus the enviornmental assessment on issues and concerns identified by the public, technical experts and regulatory agencies. The comments received through an issues scoping process are organized and evaluated to identify the VECs.

Husky Oil conducted an extensive issues scoping and stakeholder information/consultation program in preparing the Comprehensive Study for the White Rose oilfield development. This program met the requirements of the CEAA. It allowed Husky Oil to identify the VECs that are the focus of the environmental assessment conducted for the White Rose oilfield development.

The scoping/consultation program involved:

- reviewing relevant legislation and guidelines;
- reviewing the scoping document issued by the C-NOPB, DFO, EC and IC (Appendix 1.A);
- reviewing documents prepared for the Terra Nova and Hibernia oilfield developments;
- reviewing issues raised during the Terra Nova Development environmental assessment review process;
- consulting community, fishing community, business, women's and non-governmental organizations, and the general public (key informant workshops, open houses and meetings/presentations); and
- holding meetings with government departments and agencies;
- conducting media briefings and preparing press releases;
- tracking articles/stories from media sources;
- distributing project information (two mail distributions);
- establishing a toll-free telephone number (724-7244 and 1-877-724-7244);
- setting up a project-specific website (www.huskywhiterose.com);
- documenting issues and concerns, and following up when necessary; and
- using professional judgement based on the particular characteristics of the White Rose oilfield development.

The scoping/consultation program focused primarily on the areas most likely to be affected by the project. However, it also reached a geographically wider audience through meetings in other communities, with groups and organizations with a particular interest in the White Rose development, and through general solicitation of input from press releases, advertisements, website and the project information telephone number at Husky Oil's St. John's office.

A detailed report of the issues scoping and stakeholder consultation program is provided in the *White Rose Oilfield Development Public Consultation Report* (JWEL 2000). This report contains a detailed description of the scoping/consultation program and a comprehensive list of all observations, questions, comments, issues and concerns identified throughout the scoping/consultation program. Following is an overview of the program components and a synopsis of comments and issues received.

1.5.1 Regulatory Requirements

The starting point for the issues scoping process was a review of CEAA and its associated Responsible Authority's Guide (1994b). CEAA sets out the regulatory requirements for a federal environmental assessment (refer to Section 1.1). It established the initial scope for the environmental assessment.

1.5.2 C-NOPB Scoping Document

The scoping document issued by the regulatory agencies on July 21, 2000 is the principal regulatory tool providing specific direction for the environmental assessment. It was reviewed for issues and concerns to be addressed in the assessment and development application documents. A copy of the scoping document is provided in Appendix 1.A.

The scoping document states that Husky Oil must consider the factors outlined in Section 16 of CEAA, as well as issues and concerns identified during its regulatory, stakeholder and public consultation. Considerations noted in the scoping document include:

- cumulative environmental effects, including fishing activities, marine bird hunting, marine transportation, Hibernia and Terra Nova projects, and approved or reasonably foreseeable petroleum exploration activity;
- environmental assessment methodology and testable hypotheses;
- air emissions, including greenhouse gas emissions, and any implications for worker health and safety;
- description of the seabed area predicted to be affected by dredging, trenching, dredge soil disposal, drill cuttings and other discharges;
- marine and/or migratory birds using the Grand Banks and their habitat;
- marine fish, shellfish, reptiles and marine mammals, and their respective benthic and water-column habitat;
- presence of structures and/or operations associated with the project, including project related vessel traffic;
- traditional, existing and potential commercial, recreational and aboriginal/subsistence fisheries including foreign fisheries;

- discharges and emissions, including electromagnetic emissions from radio equipment and planned project discharges to the marine environment, and approach to waste management;
- accidental events, including blowouts, oil and chemical spills, chronic oil pollution and spill response;
- physical environment, including meteorological, oceanographic and seabed characteristics, sea ice and icebergs, monitoring, observation and forecasting programs, and ice management;
- environmental management, including policies for pollution prevention, environmental effects and compliance monitoring, management system auditing, training, chemical selection and management, fisheries liaison, compensation strategies for damage to fisheries and other affected parties, fish habitat compensation and emergency response;
- environmental effects monitoring (EEM), including program characteristics, parameters and hypotheses, baseline information, integration with other programs, independent/peer review of results, linking results to the environmental management system, and habitat compensation and post-dredging monitoring; and
- abandonment/decommissioning plans and monitoring.

1.5.3 Literature and Information from Previous Offshore Oil Developments

Various materials from other oil developments in the Newfoundland offshore, in particular the Terra Nova Development, were reviewed for direction in completing the environmental assessment and for any information of relevance to the White Rose oilfield development.

Husky Oil, as part of its scoping activities, reviewed the submission and presentation to the Terra Nova Development Environmental Assessment Review Panel by the Natural History Society of Newfoundland and Labrador. The submission was a reporting of concerns emerging from a review of the EIS for the Terra Nova Development. Key areas of concern included drilling fluids, produced water, oil spills, benthic communities, marine birds, sea ice and ice management, emergency response and cumulative effects.

1.5.4 Public Consultation

The public information and consultation program involved the following events.

- six key informant workshops (one each in Clarenville and Marystown, and four in St. John’s);
- eight open houses (two each in Clarenville, Marystown, Arnold’s Cove and St. John’s); and
- meetings with community, women’s, non-governmental organizations and business groups (Clarenville, Marystown, Arnold’s Cove, St. John’s, Placentia, Gander and Corner Brook).

The following tools were used to provide information and to obtain input:

- project description as submitted to the C-NOPB (on March 21, 2000) to initiate the environmental assessment processes;
- project summary booklet, which provided an overview of the proposed project, including information on the exploration history, development plan, production system, subsea installations, project schedule, environmental management, Canada-Newfoundland benefits, and environmental assessment process;
- project update booklet that highlighted what was heard throughout the scoping/consultation program as of May 2000 and what Husky Oil was doing to address the various items raised;
- display boards for the open houses (based on information from the project description, and summary and update booklets);
- comment forms (distributed at the open houses and with the project description mail out);
- project information telephone number (724-7244 and 1-877-724-7244) at Husky Oil's office in St. John's;
- project-specific website (www.huskywhiterose.com); and
- media briefings and press releases.

1.5.4.1 Key Informant Workshops

The purpose of the key informant workshops held in March 2000 was to discuss the proposed project, environmental review process and potential effects, and to ensure community issues and concerns were identified and addressed in the assessment. The workshops in Clarenville and Marystown were designed for a general discussion, while the four workshops in St. John's had specific themes, namely fisheries, environment, community and benefits. Attendance at these workshops was by invitation to key stakeholders to ensure a wide range of local interests were represented and that the group size was conducive to open discussion. A total of 76 people participated in the six workshops representing a range of community sectors and interests, including local business, transportation, housing, health, education, social services, recreation, public safety, fishing industry, environment industry, development associations, and municipal and provincial government.

The workshops involved Husky Oil representatives providing an overview of the project followed by an informal, facilitated discussion of issues and concerns. Discussions at the community and benefits workshops focused primarily on benefits related subjects, including employment and business opportunities, opportunities for women, skill requirements and training. Also discussed were accommodations and facilities for workers and their families, employee support systems, and oil spill potential and response capabilities. At the fisheries workshop, items discussed were fisheries (historical, current and future), cumulative effects, vessel traffic, exclusion zones, amount and type of activity at the site before and during development and production, waste management, oil spills and chronic pollution issues. During the environment workshop, discussion focused on seabirds, marine mammals, fish, environmental assessment process, responsibility for vessels, waste management, accidental events, chronic pollution, oil spills, cumulative effects, baseline studies and monitoring programs.

Four themes emerging from all workshops were: the need for providing timely, accurate and appropriate project information; the need for ongoing communication over the course of the project; learning from the Hibernia and Terra Nova oilfield developments; and not generating false expectations with respect to the benefits that will result from the White Rose oilfield development.

1.5.4.2 Open Houses

There were two series of open houses, with an open house being held in Clarenville, Marystown, Arnold's Cove and St. John's during each series. The open houses provided an opportunity for the general public to speak directly with Husky Oil representatives and to voice their interests or concerns. Attendance was open to all members of the public with 341 people attending the first series of open houses in March 2000, and 88 attending the second series in May/June 2000. The open houses were held from 3 pm to 9 pm, allowing people to attend at their convenience. Husky Oil representatives were responsible for presenting all information about the proposed development and answering any questions.

Advertisements for the open houses were placed in regional newspapers (weekly publications) and in *The Telegram* (daily publication), as well as broadcast on local radio stations. Posters were mailed to the town clerks in nearby communities for posting at the respective town halls and other prominent locations within the communities. These advertisements and posters described the purpose of the open houses and listed the location, date and time of the events.

The first series of open houses featured a set of displays about the proposed White Rose oilfield development, including information on oilfield location, general field information, Husky Oil land holdings and working interests on the Grand Banks, White Rose exploration history, development plan, selected production system, subsea installations, environmental management, Canada-Newfoundland benefits and environmental assessment. Displays at the second series of open houses focused on providing an update of the work undertaken for the assessment. This second set of displays highlighted what was heard throughout the scoping/consultation program and Husky Oil's plans for addressing these items.

Comment forms were distributed at both series of open houses, with 97 forms being completed during the first series of open houses and 38 completed at the second series. During the first series of open houses,77 percent of respondents indicated that they were satisfied or very satisfied with the proposed White Rose oilfield development. At the time of the second series, 91 percent of respondents indicated a level of satisfaction with the project.

The primary items discussed during the open houses and noted on the comment forms were benefits related, including employment and business opportunities, skill requirements, training, economic benefits for local communities and the province, production facility selection and developing the natural gas resources at White Rose. Other items noted were environmental effects, oil spills, ice management, and safety equipment and procedures. The four themes heard during the workshops, about learning from previous offshore oil developments, communication, project information and expectations, were also heard during the open houses.

1.5.4.3 Other Community Meetings

Husky Oil representatives met with various municipal and business groups while preparing the assessment. Husky Oil made presentations to town council and chamber of commerce representatives in the Arnold's Cove area, Clarenville, Corner Brook, Gander, Marystown, Placentia and St. John's. At each of these events, Husky Oil representatives made a brief presentation about the project and addressed questions raised by participants. Discussions focused primarily on benefits and development related items. In all, approximately 120 people participated in these presentations.

Husky Oil representatives made a presentation at a St. John's Board of Trade luncheon in April 2000 and at the annual petroleum industry conference hosted by the Newfoundland Ocean Industries Association (NOIA) in June 2000. In both cases, a brief presentation was followed by an opportunity for questions. Over 700 people participated in these sessions.

Presentations were also made to the St. John's Rotary Club, Association of Professional Engineers and Geoscientists of Newfoundland, Consulting Engineers of Newfoundland and Labrador, Canadian Association of Power Engineers, and Newfoundland and Labrador Federation of Municipalities.

Husky Oil representatives have also met with members of the Natural History Society of Newfoundland and Labrador to review and discuss project information and status.

1.5.5 Meetings with Government Departments and Agencies

Husky Oil has made significant effort to keep elected members and government officials informed about its activities. Over the last two years Husky Oil has given updates and held meetings with federal, provincial and municipal politicians to build awareness of White Rose and gain understanding of the factors that can influence the project. Federal and provincial officials such as Deputy Ministers and Assistant Deputy Ministers in key government portfolios have been briefed periodically on activities for the White Rose development. To date, Husky Oil has had approximately 100 meetings with representatives of various departments and agencies, including:

- Atlantic Canada Opportunities Agency;
- Canada-Newfoundland Offshore Petroleum Board;
- Canadian Environmental Assessment Agency;
- Department of Fisheries and Oceans;
- Department of Industry, Trade and Technology;
- Department of Mines and Energy;
- Environment Canada;
- Natural Resources Canada; and
- Women's Policy Office, Government of Newfoundland and Labrador.

These meetings focused on briefing the various government departments and agencies about Husky Oil's plans for developing the White Rose oilfield, answering questions, seeking direction with respect to regulatory requirements, and identifying possible issues and concerns.

Various individuals knowledgeable about fisheries were contacted for the socio-economic effects analysis of commercial fisheries. Individuals contacted were from federal and provincial government departments, fish processing companies and fish harvesters association. Contacts were asked to provide information on developing fisheries, the distribution of existing fisheries, plans for expanding the fleets and fishing industry infrastructure. While the primary focus of these contacts was the socio-economic effects analysis, it also served as an avenue for distributing project information to a wider audience and provided an additional opportunity for people in the fishing industry to voice any concerns. No new issues or concerns were raised.

1.5.6 Media Briefings

Husky Oil representatives have been responsive to media inquires and have endeavoured to build a positive relationship with the local Newfoundland media. Information has been provided to both provincial and national media outlets through news releases, media briefings and one-on-one interviews. A media briefing was held in November 1999 by Husky Oil officials to announce the results of the 1999 drilling program and approach for the concept evaluation. In April 2000, Husky Oil provided an update to the media on the production facility selection, why gas development is not currently feasible, an overview of the 2000 drilling program, the economics of the White Rose project and an overview of Husky Oil's other interests on Canada's east coast.

1.5.7 Tracking Media Sources

Husky Oil regularly monitored media agencies province-wide, including newspapers, radio (news reports and call-in shows) and television news programs. Any issues noted were recorded, assessed and incorporated into the issues database. Husky Oil officials followed up with reporters on issues, when warranted.

1.5.8 Project Information Distribution

Husky Oil has completed two mailings of project information. The first mailing in early May 2000 was to the key informant workshop participants and included the project description, project summary booklet and comment form from the first series of open houses. In June 2000, the project update summary was distributed to workshop participants, the Boards of Directors of the St. John's Board of Trade and NOIA, and select business and government contacts.

1.5.9 Internet and Telecommunication Sources

To improve accessibility and communication, Husky Oil established a project information telephone line and web site for the White Rose oilfield development. Both the telephone line and web site were widely advertised. The web site is updated as new information becomes available. Husky Oil has monitored these sources regularly and recorded all contacts. However, response has been limited with inquiries mainly regarding employment and business opportunities, except for one note to the web site indicating support for selecting the FPSO production facility and one requesting information on safety with respect to icebergs.

1.5.10 Issues and Concerns

The main message heard throughout the scoping/consultation program was that the majority of participants were supportive of the development and interested in seeing it proceed. There was also a strong interest in ensuring that the project proceed in an environmentally, socially and economically responsible manner.

A number of general items that apply to all aspects of the project were noted throughout the consultation program. They are:

- learn from the Hibernia and Terra Nova experience;
- ensure ongoing, two-way communication with stakeholders;
- ensure project information is accurate, timely and appropriate; and
- do not raise false expectations in relation to benefits from the project.

Items raised throughout the scoping/consultation program related to the environmental effects of the project have been incorporated in project planning and are reflected in this Comprehensive Study assessment. A synopsis of items heard from stakeholders throughout the scoping/consultation program, with the locations noted as to where they are addressed in the assessment document, is provided in Table 1.5-1. A comprehensive list of the items heard throughout the scoping/consultation program is provided in JWEL (2000).

Issues raised in the scoping/consultation program related to industrial and employment benefits, development concept, construction and operational matters and resource conservation are addressed in the project Development Application currently being prepared for submission to the C-NOPB under the *Atlantic Accord Implementation Act*.

Table 1.5–1 Summary of Comments

Comments	Where Addressed
Accidental Events	
Concern about the potential for a blowout, oil spill (all volumes) or chemical spill at the site or during transportation, and resulting effects of such accidents.	Part One, Chapter 5 Part Two, Section 7.2
Modelled physical fate of oil spills, including a description of the models and data used.	Part One, Sections 5.8, 6.10
Ability to effectively respond to oil spills resulting from the operation.	Part One, Chapter 6
Emergency response plans for all accidental events, including risk-based determination of response needs, types and location of response equipment, and time to deploy equipment.	Part One, Chapter 6
Chronic oil pollution on the Grand Banks (e.g., drilling fluids and well-head leaks), cumulative effects and perceived lack of enforcement by regulatory agencies.	Part One, Sections 4.3.4, 4.4.2, 4.4.4, 4.5.4, 5.9.2
Dumping of bilge water by ocean-going vessels.	Part One, Section 4.4.2
Criteria, ability and time required to disconnect and move the facility in an emergency.	To be addressed in Development Application
Birds	
Spatial and temporal distribution of seabirds.	Part One, Sections 3.1.4, 3.9
Habitat, feeding, breeding and migratory characteristics of relevance to the environmental assessment.	Part One, Sections 3.1.4, 3.9
Effects of project activities, oil spills and any sheens associated with regulated discharges on seabirds.	Part One, Sections 4.4.1, 4.4.2, 4.4.3, 4.4.4, 5.9.2.2
Effects of project-related aircraft overflights on bird concentrations and/or colonies.	Part One, Section 4.4.1.7, 4.4.2.8
Cumulative effects of multiple offshore developments and marine transportation on seabirds, as well as marine bird hunting activities.	Part One, Section 4.4.4
Seabirds being attracted to sewage from offshore platforms, and to lights and flaring activity on platforms.	Part One, Sections 4.4.1.1, 4.4.1.2, 4.4.1.4, 4.4.2.1, 4.4.2.2, 4.4.2.5
Bioaccumulation by birds of heavy metals associated with project discharges.	Part One, Section 4.4
Sensitive marine and/or migratory bird species using the Grand Banks.	Part One, Section 3.9.4
Monitoring programs for seabirds.	Part One, Sections 4.4.5, 7.1.2
Mitigation measures for potentially significant effects on birds.	Part One, Section 4.4
Means for assessing and documenting bird mortalities associated with project operations.	Part One, Sections 4.4.5, 7.1.2
Conflicting opinions about handling bird kills.	Part One, Section 4.4

Comments	**Where Addressed**
Business	
Need to maximize benefits to local businesses, facilities, services and suppliers.	To be addressed in Development Application
Need for appropriate contracting strategy.	To be addressed in Development Application
Need to work with and provide information to the business community, education and research institutions, and economic development organizations on a timely basis.	To be addressed in Development Application
Perceived obstacles to maximizing local benefits, such as ensuring local suppliers are competitive.	To be addressed in Development Application
Need to monitor business-related commitments.	To be addressed in Development Application
Commercial Fisheries	
Loss of access to fishing grounds due to project facilities and operations.	Part One, Section 4.3.1.1, 4.3.2.1 Part Two, Sections 7.2.1.1, 7.2.2.1, 7.2.4.1
Effects of project operations and any accidents on traditional, existing and potential commercial, recreational, aboriginal/subsistence and foreign fisheries, including consideration of the potential reopening of fisheries currently under moratoria.	Part Two, Sections 7.1, 7.2, 7.3
Cumulative effects of multiple offshore developments and related activities on fishing activities.	Part Two, Section 7.2.2
Compensation for damage related to project activities.	Part One, Sections 4.3.2.3, 7.2, 8.14 Part Two, Section 7.2, 7.3
Need for ongoing communication between industry and fishers and fisheries organizations.	Part One, Sections 8.8, 8.14 Part Two, Section 7.3
Fish tainting, real or perceived, and effect on fisheries.	Part One, Sections 4.3.1.4, 4.3.2.5, 5.9.2.1 Part Two, Section 7.2.1.5
Economy	
Need to maximize benefits to Newfoundland and Labrador, including taxes and royalties and the potential for related development.	To be addressed in Development Application
Need to facilitate local benefits by integrating site work forces into the local communities, where practical.	Part Two, Section 6.2
Need to encourage and expedite development of the natural gas reserves at White Rose.	To be addressed in Development Application
Need to maintain continuity with other oil development projects to maximize benefits and avoid “boom/bust” development.	Part Two, Sections 1.2, 4.3.2
Effect of world oil prices on project feasibility.	To be addressed in Development Application
Employment	
Need to maximize local (including women’s) employment, training and technology transfer.	To be addressed in Development Application
Project schedule and lifespan.	To be addressed in Development Application
Human resources and hiring policies, in particular local hiring and gender equity.	To be addressed in Development Application
Need to reduce out-migration trend, bring Newfoundlanders back home.	To be addressed in Development Application
Maintaining continuity for employment following the Terra Nova work to facilitate long-term growth.	To be addressed in Development Application
Need to work with and provide information to local research and education institutions.	To be addressed in Development Application

Comments	Where Addressed
Need for effective monitoring of employment-related commitments.	To be addressed in Development Application
Endangered or Special Status Species	
Sea turtles.	Part One, Sections 3.11, 4.6
Effects of planned discharges on marine life.	Comp. Study, Section 1.2.1 Part One, Sections 1.2.1, 4.3, 4.4, 4.5
Environment	
Effect of the physical environment on the project and vice versa must be considered.	Comp. Study, Section 1.7 Part One, Chapters 4, 5
Effects of the project on the biophysical environment due to any release of drilling muds, produced water, drill cuttings and other discharges, dredge spoil disposal, air pollution, sewage disposal and aircraft operation.	Part One, Chapter 4
Air emissions.	Part One, Sections 4.3.1.16, 4.3.2.13, 4.4.1.5, 4.4.2.6, 8.8.3.1, Appendix 4.A
Greenhouse gas emissions, including estimated emissions and means for their reduction and reporting.	Part One, Sections 4.3.1.16, 4.3.2.13
Meteorological, oceanographic and seabed characteristics of the project area, including extreme conditions.	Part One, Chapter 2
Site-specific sea ice and iceberg conditions, including seabed scour.	Part One, Sections 2.5, 2.6.3
Vessel traffic and routing, and environmental effects.	Comp. Study Section 1.2.1 Part One, Sections 4.3.1.17, 4.3.2.14, 4.4.1.6, 4.4.2.7, 4.5.1.5, 4.5.2.7 Part Two, Sections 7.2, 7.3
Difficulties in distinguishing actual effects of offshore oil development from natural changes in the environment.	Part One, Chapters 3, 4, 7
Need for representative baseline information for the White Rose site; concern about relying too heavily on the work of previous (Terra Nova, Hibernia) operators.	Comp. Study, Section 1.2.1
Environmental Assessment/Development Application	
Environmental assessment/development application methods, contents and schedule.	Comp. Study, Section 1.2.1 Part One, Section 4.2 Part Two, Section 2.2
Identifying testable hypotheses associated with the assessment results, where possible.	Part One, Sections 4.3.5, 5.9.3, 7.1, 7.4, 8.11
Regulatory requirements of the *Canadian Environmental Assessment Act* (triggers and Responsible Authority) and the Newfoundland and Labrador *Environmental Assessment Act* (NEAA).	Comp. Study, Section 1.1 Part One, Section 4.2 Part Two, Section 2.2.1
Understanding of the C-NOPB guidelines and the CEAA review process.	Comp. Study, Section 1.1 Part One, Section 4.2 Part Two, Section 2.2.1
Ensuring proper use of the precautionary principle, if it is used.	Part One, Section 8.10.1
Regulatory mandates of government agencies with respect to development applications and environmental assessments.	Comp. Study, Section 1.1 Part One, Section 4.2 Part Two, Section 2.2.1
Assessing long-term and cumulative effects of all users of the Grand Banks, such as other oil and gas activities, fishers, cable operators, research surveys and other vessels.	Comp. Study, Section 1.8 Part One, Sections 4.2.5, 4.3.4, 4.4.4, 4.5.4, 4.6, 5.9.2.5 Part Two, Section 7.2.2
Environmental Management	
Sewage treatment and disposal.	Part One, Sections 4.3, 4.4, 4.5, Chapter 8

Comments	Where Addressed
Planned project discharges, including characteristics, quantity and modelling (including description of the models used).	Comp. Study, Section 1.2.1 Part One, Sections 4.3, 4.4, 4.5, Chapter 8
Measures for reducing, reusing and recovering wastes that exceed specified regulations and guidelines, including best available/practicable technology.	Comp. Study, Section 1.2.1 Part One, Sections 4.3.1, 4.3.2, 8.8.3
Technical and economic feasibility of subsurface reinjection of produced water and drill cuttings associated with organic-phase drilling fluids.	Part One, Section 4.3
Environmental protection and awareness training for employees and contractors.	Part One, Section 8.2.5
Need for environmental protection and monitoring plans.	Part One, Chapters 6, 7, 8
Nature of dredging activity and handling of dredge spoils, and characterization of disposal sites.	Part One, Section 4.2.1.1, 4.3.1.1
Ice management and mitigation procedures.	Part One, Sections 2.5.4, 6.8.2
Responsibility for ships and their actions, including regulations for second-leg tankers.	Comp. Study, Section 1.2.1
Environmental management system that addresses pollution prevention, monitoring, auditing of the management system, environmental training, chemical selection and management, fisheries liaison and compensation for project-related damage.	Part One, Chapter 8
Abandonment and/or decommissioning plans and monitoring.	Part One, Chapter 7
Fish and Fish Habitat	
Characterization of (information on) fish habitat conditions at the project area, affected area and region.	Part One, Chapter 3
Distribution and abundance of species using the potentially affected area, including consideration of life stages.	Part One, Chapter 3
Effect of project activities, considering cumulative effects, lethal and sublethal effects, species interrelationships, fish health and productivity, and amount of habitat affected.	Part One, Sections 4.3, 5.9
Effect of any oil spill and planned discharges on fish and fish habitat.	Part One, Sections 4.3, 5.9
Monitoring programs for fish and fish habitat.	Part One, Sections 4.3.5, 5.9.3, Chapter 7
Fish habitat compensation strategies and options.	Part One, Sections 4.3.2.3, 7.2
Benthic communities.	Part One, Sections 3.4, 4.3
Health and Safety	
Need for rigorous safety standards, and procedures for monitoring and enforcing safety requirements.	To be addressed in the Development Application
Ability to operate in severe weather conditions.	To be addressed in the Development Application
Need for appropriate and effective safety and evacuation equipment and procedures.	To be addressed in the Development Application
Need to optimize the location of accommodations on the production facility relative to the production/processing activity.	To be addressed in the Development Application
Effects of electromagnetic emissions from radio equipment on personnel safety and mitigation measures for emissions.	Part One, Section 8.8.3.6
Air emissions and any implications for the health and safety of workers that may be exposed.	Part One, Sections 4.3.1.16, 4.3.2.13, 4.4.1.5, 4.4.2.6, 8.8.3.1, Appendix 4.A
Need for a complaint reporting system.	To be addressed in the Development Application
Need for employee and family assistance/support programs.	Part Two, Section 5.4
Marine Mammals	
Effects of project activities, any oil spills and planned discharges on marine mammals.	Part One, Sections 4.5, 5.9.2.3
Monitoring programs for marine mammals.	Part One, Section 4.4.5

Comments	Where Addressed
Monitoring	
Need for a monitoring process for all aspects of the project, including structures, operations, benefits and effects, with auditing of components.	Parts One and Two
Nature and frequency of compliance monitoring.	Part One, Section 8.12
Physical environment monitoring, observation and forecasting programs.	Part One, Chapters 2, 6
Environmental effects monitoring for routine and accidental events, and process for designing the monitoring program.	Part One, Sections, 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11, Chapter 7 Part Two, Section 7.3.2
Monitoring parameters (marine birds, reptiles and mammals, fisheries, fish health/productivity and taint, fish habitat and marine environmental quality) and selection rationale.	Part One, Sections, 4.2.7, 4.3.5, 4.4.5, 4.5.5, 5.9.3, 6.10.4, 8.11, Chapter 7 Part Two, Section 7.3.2
Linking monitoring hypotheses to testable hypotheses.	Part One, Section 7.1
Need for baseline studies and site-specific data.	Comp. Study, Appendix 1.B Part One, Section 7.6
Need to integrate monitoring programs with other projects such as Hibernia and Terra Nova.	Part One, Section 7.3
Distinguishing “signal” from “noise” in monitoring programs.	Part One, Section 4.3.5
Tying monitoring results to environmental management.	Part One, Section 7.1, 8.11
Independent/peer review of monitoring results.	Part One, Section 7.6
Potential requirements for fish habitat compensation and post-dredging monitoring.	Part One, Sections 4.2.1, 4.3, 7.2
Public Involvement	
Availability of the concept selection document to the public.	To be addressed in Development Application
Community liaison and/or local Husky Oil contact in communities.	Parts One and Two
Information on the regulatory and public review process, and schedule/timing.	Part One, Section 4.2.1 Part Two, Section 2.2.1
Services and Infrastructure	
Accommodations for employees – construction camp and hotels versus living in communities.	Part Two, Section 6.2
Location of recreation and support facilities for employees and their families.	Part Two, Section 5.6
Traffic concerns due to project-related activity.	Part Two, Section 6.3
Capacity of local communities to accommodate in-migration.	Part Two, Chapters 5, 6
Health and social service requirements associated with the project.	Part Two, Sections 5.3, 5.4
Effects of in-migration and increased affluence on onshore health and social services.	Part Two, Sections 5.3, 5.4
Technical/Project Description	
Concept selection process, selected production alternative and rationale for selection.	To be addressed in Development Application
Plans and timing for developing both the oil and gas at White Rose.	To be addressed in Development Application
Project infrastructure and activities, including activity before the actual start of the development.	To be addressed in Development Application
Project-related traffic, including vessel types, volumes, routing and schedules.	Comp. Study, Section 1.2 Part One, Sections 4.3.1.17, 4.3.2.14, 4.4.1.6, 4.4.2.7, 4.5.1.5, 4.5.2.7 Part Two, Sections 7.2, 7.3
Oil storage alternatives both onshore and offshore.	To be addressed in Development Application

1.6 DATA SOURCES

In describing the Regional Setting, both the physical, biological and commercial fishery, a number of primary data sources were accessed. A list of these sources was provided to the C-NOPB in June 2000.

1.7 EFFECTS OF THE ENVIRONMENT ON THE PROJECT

The White Rose oilfield project will be specifically designed to withstand the harsh sea and weather environment in the North Atlantic.

Chapter 2 of the EIS (Part One) details the harsh physical conditions of the White Rose site, including the sea state, ocean currents, ice, winds, waves, and weather variables. The appropriate data were used in developing the basis for design. For example, physical considerations, such as ice accretion, will be built into any loadings calculated for above-surface structures.

Ice is a serious consideration, and because of the presence and likelihood of icebergs, all well manifolds will be protected in glory holes, flowlines may be trenched and will be able to be flushed and the turret will be designed to enable disconnection of the FPSO to allow it to move off location. A joint industry ice management plan will also be in place to facilitate ice monitoring and manage and provide guidance for decisions relating to vessel disconnect.

Biofouling, or the colonization of structures by epibenthic communities, is also considered in engineering design. Procedures are developed to remove the biofouling in order to protect the asset from deterioration. Biofouling is discussed in detail in Section 4.3.1.1 of the EIS (Part One).

1.8 CUMULATIVE EFFECTS ANALYSIS

The EIS (Part One) and SEIS (Part Two) used an integrated approach to cumulative effects analysis. Cumulative environmental effects are addressed for each project activity within each VEC in appropriate levels of detail, depending upon the amount of information available, the results of issue scoping sessions, and potential for interaction of the activity with the VECs. The projects and activities considered are those which are ongoing or likely to proceed, and have therefore been issued permits, licenses, leases, or some other form of approval, as specified by the Canadian Environmental Assessment Agency in the "Reference Guide: Addressing Cumulative Effects" included in the "Responsible Authority's Guide" (CEAA 1994b) and the updated Practitioner’s Guide (CEAA 1999).

Projects and activities considered in the cumulative effects assessment included:

- White Rose within-project cumulative impacts, particularly between the three project phases: (1) development, (2) production, and (3) decommissioning or abandonment and for accidental events. For the most part, and unless otherwise indicated, within-project cumulative assessment is fully integrated within the White Rose assessment;
- Hibernia (an existing offshore oil development on the Grand Banks);
- Terra Nova (an in-progress offshore oil development on the Grand Banks between Hibernia and White Rose);
- present and future offshore oil exploration activity (seismic surveys and exploratory drilling). On the Grand Banks for 2000-2001, there are four approved seismic (J. McIntyre, pers. comm.) and three approved drilling programs and a similar level of activity is assumed for the foreseeable future. [Note that there are 24 current exploration licences for the Grand Banks (C-NOPB website, June 9, 2000)];
- commercial fisheries (see SEIS (Part Two));
- marine transportation (tankers, cargo ships, supply vessels, fishing vessel transits, etc.); and
- (for marine birds) hunting activities.

The above projects and activities have all received some form of formal approval and thus can be considered ongoing or likely to proceed as per CEAA (1994c; 1999).

2 PROJECT DESCRIPTION

This chapter provides a brief overview of the technical and operational considerations related to the White Rose oilfield development. Detailed description of the project techncial aspects will be contained in the Development Application to be submitted to the C-NOPB.

Developing the White Rose oilfield will include:

- design engineering of the selected production system;
- procuring the goods and services required for the production system;
- constructing or modifying various components of the production system;
- installing and commissioning the production system at the White Rose site;
- drilling and completing up to 18 to 25 wells (production, water injection and gas injection);
- production, operation, maintenance and support services over the producing life of the field, expected to be approximately 14 years; and
- decommissioning and removing the production system from the White Rose site, and removing and/or abandoning the subsea infrastructure.

2.1 RESERVOIR ENGINEERING

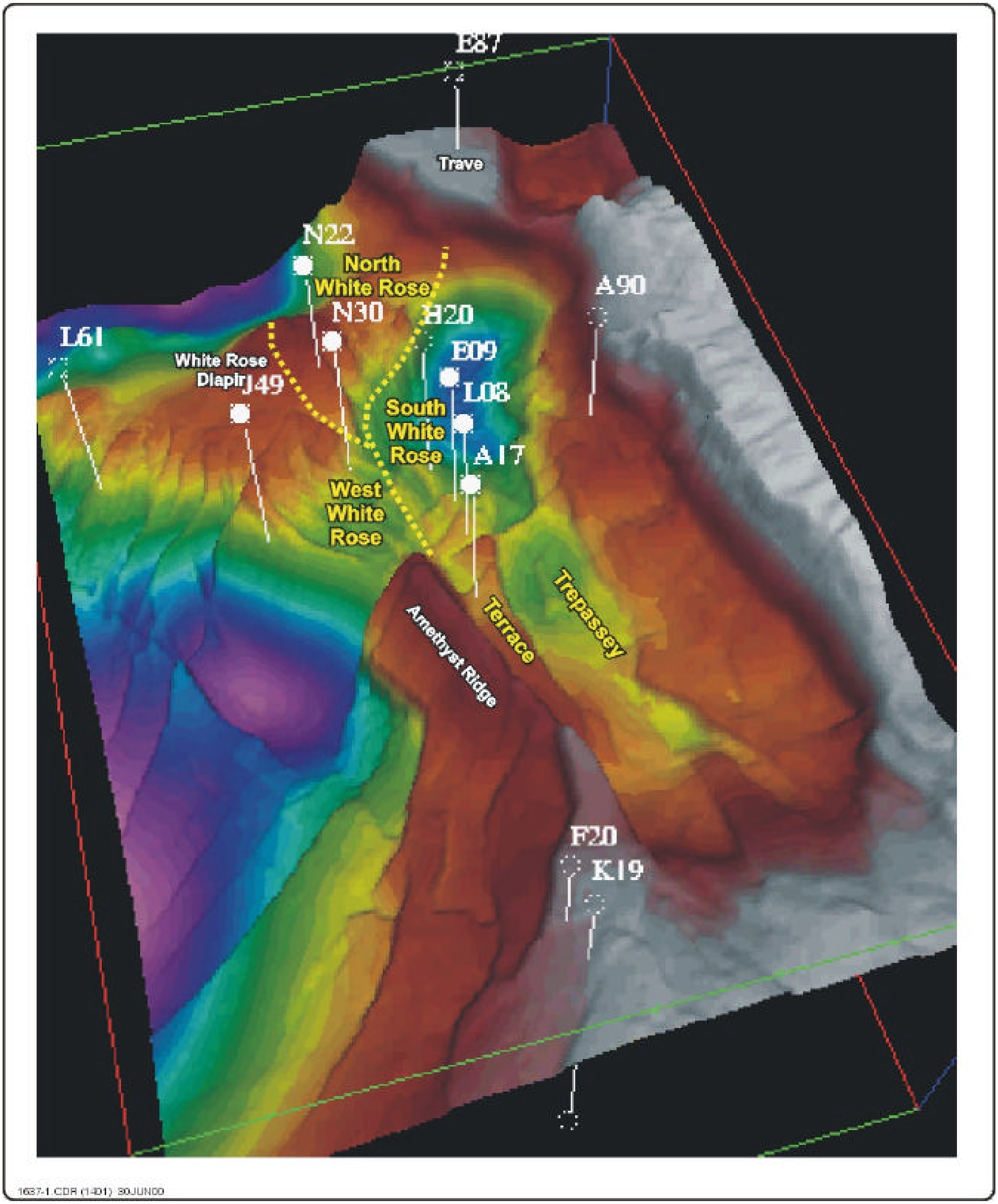
2.1.1 Reservoir Quality and In Place Resource Assessments

Twenty-five drill stem tests have been carried out in the White Rose field to assist in evaluating reservoir production capabilities and determine fluid properties. Results indicate that each of the three Avalon pools has an oil leg with an associated gas cap and underlying water. The oil-water and gas-oil contacts are different for each pool confirming that there are sealing faults in the field. The oil is a typical Jeanne d'Arc Basin waxy crude with an average quality of approximately 30° API. The reservoirs have fine to very fine sandstone with a relatively low average permeability in the order of 100 milliDarcies (mD). In addition, there are several calcite-cemented zones that may hinder production.

2.1.1.1 South Avalon Pool

The South Avalon pool has been delineated by four wells (E-09, L-08, A-17 and H-20) (Figure 2.1-1). The pool has a 117 m oil leg and contains approximately 65 percent of the original oil in place (OOIP) in the field. The pool is expected to contain between 114 and 138 million m^3 of oil, with proven plus probable (P50) volumes of 126 million m^3.

Figure 2.1–1 Delineation Well Locations



The gas cap in the pool has an average thickness of 81 m and is expected to contain between 8.2 and 15.5 billion m^3 of the original gas in place (OGIP).

The above volumes do not include the results of the recently drilled H-20 well. It is expected that the results of this well will only marginally reduce the in place volumes.

This pool has better reservoir quality than the other pools with an estimated average permeability of approximately 127 milliDarcies (mD). Due to the low permeability and the proximity of the gas cap, horizontal development wells will be required to ensure adequate production rates and maximum oil recoveries. With horizontal well lengths in the order of 2,000 m, a typical production well in the pool should initially be capable of producing 3,600 m^3 of oil per day.

2.1.1.2 North Avalon Pool

Two wells, N-22 and N-30, have been drilled in the North Avalon pool. Both of the wells encountered and tested gas. The average gas column thickness for the pool is expected to be around 177 m and contain between 41 and 54 billion m^3 of the OGIP. This represents about 50 percent of the gas in the Avalon Formation.

The N-30 well encountered 15 m of oil at the bottom of the Avalon Formation. Extrapolating to the common water gradient in the field, the pool is expected to have a 56 m oil column. The OOIP for the pool is estimated to be between 25 and 32 million m^3. Proven plus probable (P50) volumes are estimated to be 29 million m^3 or about 15 percent of the oil in place in the field.

On average, the North Avalon pool is expected to be of poorer reservoir quality than the South Avalon pool with an average permeability in the order of 95 mD.

2.1.1.3 West Avalon Pool

Only one well, J-49, has been drilled in this pool. The pool is expected to have an average gas column thickness of 122 m and an oil column of 59 m. The OGIP for the pool is estimated to be between 23 and 37 billion m^3. The OOIP is estimated to be between 32 and 42 million m^3 with proven plus probable (P50) volumes of 37 million m^3. On this basis the pool is expected to contain about 35 percent OGIP and 20 percent of the OOIP in the Avalon Formation.

This pool is also expected to be of poorer reservoir quality than the South Avalon pool with an average permeability in the order of 90 mD.

2.1.2 Reservoir Exploitation

2.1.2.1 Reservoir Simulation Model – South Avalon Pool

A three-dimensional reservoir model was developed for the South Avalon pool to evaluate depletion options for the pool. For reference case reservoir performance determinations, all faults were assumed to be sealing.

A waterflood scheme was used for the reference case development. Several model runs were made to determine the horizontal well locations that would result in optimum recoveries from the model. A total of ten production wells and seven water injection wells were required to optimize reservoir performance in the model. Horizontal water injection wells were placed well below the oil-water contact to ensure dispersion of the injection water. The location of the horizontal oil producers was based on optimizing recoveries, while maximizing the time to water and/or gas break through.

A fundamental assumption for the waterflood development case is excess produced gas is conserved by reinjecting it into another pool in the White Rose field. Current plans are to drill the first gas injector in White Rose North Avalon pool in the N-22 area. After some reservoir response is seen a decision will be made as to the number, timing and location for additional gas injectors, if they are required. Areas for potential future gas injector locations include the North Avalon pool, the West Avalon pool and the south end of the Terrace block in the South Avalon pool.

Three other development options were evaluated for the South Avalon pool. They were:

- reinjecting all excess produced gas (net of fuel requirements) into the southern portion of the South Avalon pool;
- reinjecting excess produced gas (net of fuel requirements) into fault blocks across the field; and
- reinjecting only a portion of produced gas cap gas to maintain original gas-oil contacts.

In cases where all produced gas is reinjected into the producing pool, recoveries are reduced significantly. For the partial reinjection cases recoveries are not affected as significantly, but additional gas injection wells would be required as there would be gas injection both within and outside the pool.

In all cases, reinjection of gas into the pool increases gas handling requirements due to earlier and more significant breakthrough volumes. The increased gas production rates would increase gas compression requirements and reduce project economics.

The water injection reference case maximizes recoveries and minimizes gas handling requirements. Water handling and total fluid requirements are larger in the reference case, but can be managed much more easily than large gas volumes.

An evaluation of whether vertical or deviated wells could be used for oil production rather than horizontal wells showed that significant deviations of wells from horizontal could significantly reduce field recoveries by allowing early gas or water breakthrough. This supports the use of horizontal producers. Further assessment of the use of deviated wells will be carried out as more reservoir information becomes available.

2.1.2.2 South Avalon Oil Reserves and Production Forecasts

The results of the simulation sensitivity work were used to develop probabilistic recovery factor and reserve ranges for the South Avalon pool. The recovery factor for the pool under waterflood is expected to be between 24 and 39 percent, with a reference case (P50) value of approximately 31 percent. This range of recovery factors was applied to the probabilistic OOIP range for the pool resulting in recoverable oil reserves ranging from 34 and 46 million m^3. The reference case (P50) reserves is 36 million m^3 assuming no production from the two northern fault blocks in the South Avalon pool, reflecting the results of the H-20 well.

2.1.2.3 Development Drilling Schedule

Several of the development wells will be pre-drilled prior to production start-up. The proposed strategy is to pre-drill sufficient wells prior to First Oil to have the capability of producing at facility design rates. There will also be pre-drilled water injection wells to provide appropriate initial pressure support and a pre-drilled well for gas injection so that gas conservation and minimization of flaring can commence as soon as possible. To meet these objectives, up to 10 wells will need to be drilled prior to First Oil and drilling will need to commence approximately two years prior to First Oil.

2.2 DESIGN CRITERIA

The following are the key objectives/philosophies of the project to ensure that the value of the asset is maximized, consistent with the wider business objectives of Husky Oil and co-venturer, Petro-Canada:

- Safety is of prime concern and the project will provide a safe and healthy working environment through the design and operation of the facilities for all personnel. Formal safety assessments and the reporting of safety performance will be undertaken throughout the duration of the project.
- Decision-making will be on a life-cycle basis.
- Integrity of the project (in terms of personnel safety, environmental protection, property integrity and business interruption) is crucial. The project will employ risk management and value engineering principles.
- Sizing of tender parcels and equipment specifications will take into consideration Canadian and Newfoundland suppliers and contractors who can demonstrate appropriate experience and deliver technical competence and commercial competitiveness.
- Availability targets will be developed for each production and operations system.
- A high priority will be placed on environmental protection and compliance with all pertinent laws and regulations, and Husky Oil's environmental management system. The project will be required to demonstrate that objectives are being met during regular performance review, supplemented by periodic auditing.
- As far as practical, the design will ensure that construction, testing, integration and pre-commissioning are performed at the quayside with offshore activities limited to hook-up and final commissioning.
- White Rose production facilities will be designed for a target service life of 20 years.

Engineering and design practices will be common across the project and all designs will conform to relevant codes and standards. Generally accepted international standards, such as the American National Standards Institute/American Society of Mechanical Engineers specifications and American Petroleum Institute recommended practices, will be applied, as appropriate.

The FPSO design will be targeted for the following operational capabilities:

- disconnect from its mooring on the approach of an iceberg of mass greater than 100,000 t;
- withstand impact of icebergs up to 100,000 t;
- continuous production in one-year storm conditions;
- station-keeping in 100-year storm conditions;
- operation in moderate sea-ice up to concentrations of 50 percent ice cover; and
- normal planned disconnection during one-year storm conditions.

The operating manuals will define the limits for operation imposed by safety, equipment and environmental considerations.

The South White Rose oilfield will be developed using subsea completions tied back to a mono-hull type FPSO unit, permanently moored in approximately 125 m of water, with the crude oil transported to market by shuttle tankers. Accommodation, production separation, water injection, gas lift, gas reinjection, and crude export facilities will be provided on the FPSO.

Subsea wellheads will be located in glory holes to protect them from iceberg scour. Equipment within the glory hole will be designed such that the top is a minimum of 2 to 3 m below the mudline. Manifolds and flowlines will be designed fail-safe to minimize any harmful environmental consequences should they fail or be damaged. Flowline systems will be designed to allow the flushing/purging of production lines in the case of iceberg scour risk. Their location on the seafloor will give ease of access for inspection, testing, repair, replacement or removal. Emergency shutdown valves will be provided. These will ensure the safety of personnel and minimize environmental effects in the event of accidental damage to the production facilities.

The FPSO will require a storage capacity of approximately 111,000 and 135,000 m^3 (700,000 and 850,000 barrels), representing about eight to ten days oil production. It must be capable of handling peak oil production of between 12,000 and 18,000 m^3 (75,000 to 110,000 barrels) per day**,** peak gas production of between 6 million and 7 million m^3 per day and peak water production of between 15,000 and 30,000 m^3 per day. Due to the presence of icebergs at the field location, the FPSO will have the added capability to disconnect and move off location under its own power.

Side scan sonar images of the White Rose area indicate that the surficial geology is a thin veneer of fine to medium grained sand over a coarser substrate, consisting of sand and gravel. Occasional occurrences of gently-sloped gravel mounds in the area may correspond with old iceberg scour berms.

Past interpretations of biota present in seabed photographs have suggested that the seabed is relatively stable, with relatively little sedimentary transport within the region. This is supported by recent mapping exercises within the region. These clearly display anchor marks from old drilling programs, preserved after 15 to 20 years.

2.2.1 Well Fluids and Product Specification

2.2.1.1 Produced Oil Characteristics

Typical Avalon oil characteristics are provided in Table 2.2-1.

Table 2.2–1 Typical Avalon Oil Characteristics

Characteristic	Value
Component	
N_2	0.54 (mol %)
CO_2	1.04 (mol %)
H_2S	0.00 (mol %)
Methane	48.83 (mol %)
Ethane	4.20 (mol %)
Propane	2.88 (mol %)
i-Butane	0.52 (mol %)
n-Butane	2.13 (mol %)
i-Pentane	0.88 (mol %)
n-Pentane	1.11 (mol %)
Hexane+	37.87 (mol %)
Total	100.00 (mol %)
Pour Point	< 12 °C
Wax appearance temperature	45 °C
Wax Content	8.0% by weight

Carbon dioxide is present in the well stream fluids in the range of 1 to 2 mol % and will create some corrosion concerns when water is produced. Suitable materials to resist CO_2 corrosion will therefore be specified.

Although no significant sulphur compounds have been detected in the well stream fluids, experience suggests that the introduction of seawater injection tends to produce small levels of H_2S in the reservoir. Suitable materials will be specified to meet NACE requirements for sour service as appropriate.

2.2.1.2 Produced Water Characteristics

Significant water production is not expected during the early life of the field. Any water produced initially will be primarily formation water. A typical expected composition of formation water is shown in Table 2.2-2.

Table 2.2–2 Typical Formation Water Composition

Ion	Concentration (mg/L)
Na	15,860
K	250
Ca	757
Mg	102
Ba	3.01
Sr	122
Fe	2.63
B	56.4
Mn	0.25
Cl	25,550
Br	53
I	58.2
HCO_3	1068
SO_4	390

All produced water will be treated and disposed of directly overboard and will meet the requirements of the C-NOPB Offshore Waste Treatment Guidelines (for futher information on produced water discharge, refer to Part One, Section 4.3).

Carbonate scaling is expected to occur in the producing wells as a result of the presence of carbon dioxide/bicarbonate ions in the reservoir fluids. Barium/strontium sulphate scaling may also be a problem in the producers after water breakthrough as a result of formation water/injection water incompatibility. Additional work is planned to better define the design basis for scaling.

2.3 DEVELOPMENT DRILLING AND COMPLETIONS

The White Rose oilfield was discovered in 1988 with the drilling of the E-09 well. Since that time, four additional delineation wells were drilled into the White Rose structure. They are L-08, A-17, N-30, and H-20. The first three of these wells were suspended. H-20 was abandoned. However, since they did not include options for iceberg protection, at present there are no plans for them to be used in the development of the White Rose oilfield.

Horizontal wells are being considered in the pay zone to provide increased productivity. Wells will have an average horizontal departure of 4,000 m and a horizontal section through the reservoir of between 2,000 to 2,500 m. Well profiles have a preliminary maximum design build rate of 3°/30 m.

A 914-mm conductor hole will be drilled to approximately 250 m below the rotary table on the drilling rig and a 762-mm conductor casing will be run and cemented to seafloor. A 406-mm hole is then planned to approximately 800 to 900-m below rotary table. The 340-mm surface casing will be cemented to the sea floor.

The 311-mm main hole will then be drilled to either the top of the Avalon Formation or possibly to some deeper depth in high-angle or horizontal wells. The production casing will be set at this point. The depth in high-angle wells will depend upon sealing off the gas cap in the reservoir.

The upper section of the 244-mm production casing may have to be increased in diameter to accommodate the surface controlled subsurface safety valve (SCSSV).

A 216-mm hole will be drilled to TD and either a 178 mm or a 140 mm liner will be run (cemented or uncemented). The well may also be completed open hole.

2.3.1 Drilling Fluid Program

The mechanism of formation damage in the reservoir will be one of the main drivers of the drilling and completion fluid design.

The drilling fluids used will be optimized to reduce fluid loss, to control rheology, and maintain hole stability. The drilling fluid program will be similar to that used on the past delineation wells. Seawater with prehydrated gel muds or polymer muds are planned for the top intervals of the well to the surface casing setting depth.

A water or synthetic-based system will be used for the intermediate hole depending on the well profile. The intention would be to use water-based mud systems in this hole section as long as the well bore stability and drag are acceptable. Synthetic-based muds (SBMs) are the most reliable method of managing hole stability and they also provide lubricity to lower drilling string torque and drag.

One of the objectives of the ongoing core and fluids studies is to identify the most likely damage mechanism(s) for the Avalon Formation that may hinder the flow of fluids during production. Once the mechanism(s) has been isolated, mud formulations will be tested to ensure that the fluid selected has minimal damaging characteristics or that any damage can be easily cleaned up and treated.

The mud system will also have to be tested and evaluated on the other design aspects. There will be a need to balance the fluid design against all the well design requirements.

2.3.2 Cementing Program

The cementing program will be similar to that used on past delineation wells. Conductor and surface casings will be cemented to the seafloor. The production casing will be cemented high enough to prevent future casing instability and to isolate permeable zones. To ensure a leak-off path for trapped fluid expansion during production, production casing will not be cemented into the previous shoe.

2.3.3 Wellhead Design

The selection of a subsea wellhead system is still ongoing. The choice of either template or clustered wells is not finalized. Subsea well protection for template and cluster wells will be by dredged glory holes. On satellite injection wells, drilled glory holes and caisson systems are being considered.

2.3.4 Production Wells

2.3.4.1 Completion Program

Prior to the start of production, all wells in a given glory hole will likely be batch completed after being drilled and temporarily suspended. White Rose development wells prior to First Oil will be batch completed to take advantage of operational efficiencies. A simplified summary of the operations involved in a typical completion is outlined below for a 140-mm monobore completion. At the end of batch drilling operations the wells will be left with appropriate barriers in place.

- Inspect wellhead and retrieve external debris cover.
- Run in drilling BOP and riser. Connect to subsea tree.
- Pressure test BOP and subsea tree.
- Pull wellhead plug and bridge plug.
- Clean out to liner top. Clean out to bottom of liner.
- Run casing scrapers over 244-mm casing and 140-mm liner.
- Circulate well to clear brine to remove drilling fluid and cement cuttings.
- Run permanent production packer on work string.
- Circulate annulus to packer fluid prior to setting packer hydraulically.
- Run in 140-mm tubing, complete with packer seal assembly, expansion assembly, gas lift side-pocket mandrels, permanent downhole gauges, tubing-retrievable SCSSVs and control line.
- Stab into polish bore receptacle and land tubing hanger.
- Pressure test packer and SCSSV.
- Perforate with coil tubing-conveyed guns.

- Flow well for a short clean up and snub out guns.
- Clean up and test well.
- Displace drilling riser to water.
- Remove drilling BOP and riser.
- Install debris cover.

2.3.4.2 Production Trees

Production trees will be located in open glory holes for iceberg scour protection. Installation will be through the moonpool of the drilling and completion MODU. As with all subsea facilities, production trees will be selected to provide diverless installation, operation, inspection and maintenance. The trees will be either vertical or horizontal type capable of installation on the 476 mm wellheads. Vertical subsea trees have valves located in line vertically over the production or injection bores. Horizontal trees have tubing hanger plugs as vertical barriers and the master valves are located on the side outlets.

2.3.4.3 Completion Fluids

Separate completion fluids will be used for cleaning out the well after drilling, providing a benign environment in the packer annulus and for perforation operations. The well is cleaned out at the start of completion operations to ensure clean casing surfaces for packer seals and to remove any debris which could impair production equipment operations. This fluid will be seawater based and facilitates circulating up cement cuttings and contamination remaining after the liner cement job. Viscous polymer gelled fluid pills may be required to sweep the hole clean to total depth, especially over the horizontal sections.

Corrosion inhibited and oxygen scavenged fluid is circulated into the annulus between the completion tubing and production casing above the production packer to prevent corrosion of the completion equipment.

The perforating fluid provides a predetermined measure of hydrostatic head which controls the initial direction of flow after perforating. Work is ongoing to determine whether an overbalanced or underbalanced perforating system will be used for White Rose development wells. If an underbalanced system is used where flow is into the wellbore then either a nitrogen cushion or an oil based fluid will be used. An overbalance system will likely employ a clean brine fluid. The perforating fluid will also be designed to prevent any adverse fluid interaction with the formation.

2.3.5 Injection Wells

2.3.5.1 Well Designs

Current water injection well design is for continuous injection of 2,000 to 6,000 m^3/day of seawater per well with a maximum of up to 9,000 m^3/day. To ensure adequate capacity, it is likely the water injection wells will be horizontal with 178-mm monobore completion or 140-mm conventional completion. As mentioned previously, gas injection wells are required to facilitate conservation and possibly aid reservoir pressure maintenance. The gas injection wells will be designed for continuous injection of 1,000 to 3,000 10^3m^3/d gas per well with a maximum of up to 4,000 10^3m^3/day gas. For project equipment synergy and to simplify completions and workovers, injection trees will likely be similar in specifications and design to the production trees.

2.3.5.2 Completion Fluids

Provisions for gas lift and chemical injection complete with remotely operated barrier valves will be incorporated into the tree design. The production trees will also have a data cable path for the permanent downhole gauges. Subsea tree controls will also enable lock out from the FPSO during workover operations to prevent accidental operation of equipment when the workover vessel is connected to the wellhead.

The production subsea tree equipment will be rated to at least 34.5 MPa based on a maximum expected pressure at surface of 23.1 MPa. The maximum surface pressure was calculated from the original reservoir pressure with gas filled tubing.

2.4 PRODUCTION AND EXPORT SYSTEMS

2.4.1 Steel FPSO

2.4.1.1 Vessel Hull

The FPSO (Figure 2.4-1) hull will be approximately 200 to 300 m in length, and will support a topsides process plant.

Figure 2.4–1 Typical North Sea Steel FPSO Facility

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The vessel will be ice-strengthened as necessary and the hull should be capable of accepting the following ice criteria:

- 100,000 t iceberg at 0.5 m/s;
- pack ice, 0.3 m thick; and
- 5/10 (50 percent) ice cover.

The vessel will have a storage capacity commensurate with throughput, and offloading frequency. Typically this will be between 111,000 to 135,000 m^3.

The vessel will incorporate a double hull construction and will have a segregated ballast system.

The layout of tanks will be such as to maximize storage while maintaining sufficient ballast capacity.

Structural Design Requirements

In addition to the ice-strengthening detailed above, the FPSO will be designed for the demands of Grand Banks operation and to withstand (as a minimum) the loads and motions imposed by the following:

- the 100-year return period, extreme environmental conditions for the full range of FPSO operational draft, heel and trim;
- transit conditions from fabrication and assembly locations to offshore location; and
- sloshing within the tanks.

Due to the extreme environmental conditions of the Grand Banks, particular attention will be paid to hull ultimate strength and fatigue life.

General Design Requirements

The following design goals are considered the minimum requirements to obtain safe and effective vessel operation over the life of the field:

- the vessel and moorings will be designed in accordance with Lloyds Register's Guidance Notes for Structural and Mooring Aspects of Ship Type FSU and FPSO Units at a Fixed Location or equivalent;
- the main detail design features of the FPSO hull will be designed so that in-service inspection and maintenance can be undertaken;
- the hull will be designed to efficiently integrate the support requirements for the topsides facilities and all other main deck structures and equipment;

- the hull will be designed to consider possible operational impacts from supply boats. The structural response will be designed to be compatible with the Safety Case for the vessel;
- vessel motions will be central to the safe and efficient operation of the vessel and be such as to have no significant adverse effect on availability for production;
- vessel intact and damage stability will comply with certification authority requirements, MARPOL 1973/78 Regulation 25, and IMO Resolutions A562 & A206;
- vessel will have adequate propulsion for manoeuvring to avoid icebergs after disconnection of mooring and riser lines;
- corrosion protection will be provided for steel hull and turret for the full design life;
- the toughness and strength of the material in the hull will be compatible with the anticipated operating temperatures and stresses;
- fatigue will be fully addressed during hull design and testing;
- topsides modules/ pre-assembled units (PAUs)/skids will be located at such an elevation as to avoid green water on the deck of the vessel. This will be verified by model testing. Equipment below the level of the modules/ PAUs/skids will be provided with protection from the occurrence of green water; and
- a full model testing program will be completed.

Dynamic Positioning System.

The requirement for a passive or dynamic positioning system is to be fully evaluated considering the following:

- the mooring system in the 100 year return period condition;
- station keeping in a disconnected scenario; and
- disconnection and reconnection.

Marine Systems

Marine systems integrated within the hull will include the following:

- cargo handling;
- ballast;
- propulsion;
- bilge;
- hull power distribution;
- fire and gas detection;
- fire fighting for pump room, machinery spaces and accommodation;
- inert gas;

- gas freeing;
- crude oil washing system/tank cleaning;
- tank gauging;
- ballast tank gas detection;
- steam heating of cargo tanks;
- hydraulic control system for remotely actuated valves;
- diesel;
- fresh water and potable water; and
- sewage treatment.

The cargo control console, ballast controls and a monitoring/alarm system for all marine systems will be located in the FPSO Central Control Room.

In addition to the above, the cargo tanks will be fitted with a pressure monitoring system capable of detecting pressures abnormally high or low relative to atmospheric that may endanger the vessel. This system will provide both visual and audible alarms in the FPSO Central Control Room.

Safety Equipment

The vessel will be provided with a minimum of 200 percent capacity in persons on board in lifeboats and 200 percent capacity in life rafts. Lifeboats and life rafts will be located close to the temporary refuge and on both sides of the vessel. Additional lifeboat(s) and life rafts will be provided at other suitable locations on the vessel. All safety equipment will meet international marine requirements and Canadian regulations. A secondary muster point will be provided.

Accommodation

Accommodations will be either at the stern or at the bow of the vessel. The skids containing oil and gas production facilities will be located furthest away from the accommodation as is possible. Typical manning levels will range from between 45 to 50 steady state crew, to between 80 to 85 with start up resources. The accommodation requirement for the FPSO will be addressed and will consider the requirements for normal operation and also offshore hook-up and commissioning and maintenance operations. Utilities, such as the galley and mess, food storage areas, change rooms and laundry, potable water and sewage treatment will be sized accordingly. Other facilities provided will include office, recreational, sick bay, and entertainment amenities.

Helicopter Operations

The FPSO will be capable of accommodating an Aerospatiale Super-Puma, EH101 or equivalent helicopter. The helideck will be designed to comply with governing legislation and for 1.5 x Super-Puma overall length (19.7 m). The helideck structure will be capable of accepting loads from SAR helicopters. Refuelling facilities will be installed.

Mechanical Handling

Offshore rated cranes of sufficient type and number will be provided to allow safe and efficient re-supply, operation and maintenance of the FPSO.

Arrangements will be made for the safe and easy handling of provisions to the galley storage spaces, and handling of equipment between the process and utility areas on deck and the workshop and stores areas.

2.4.1.2 Topside Facilities

The White Rose production facilities will be designed to produce 12,000 to 18,000 m^3/day of stabilized crude oil for shuttle tanker transportation. The gas handling facilities will be designed to process 3 to 7 x $10^6 m^3$/day of gas. The production facilities will handle 15,000 to 30,000 m^3/day of produced water. The facilities will handle all the oil, gas and water produced.

The topside facilities will primarily be on a horizontal plane raised above the vessel deck. It is envisaged that the topsides will be configured in PAUs, modules or skids, the number and size of which has not yet been determined. The configuration and layout of the modules/skids/PAUs will be determined giving consideration to Canadian/Newfoundland fabrication capability, safety, operability, maintainability, constructability, construction sequence, schedule, installation, hook-up and commissioning. The precommissioning and functional testing of the modules/skids/PAUs will be maximized prior to departure from the fabrication site to the at-shore hook-up and commissioning site.

The main topside facilities are expected to consist of the following:

- production from subsea wells;
- two stage oil stabilization;
- crude heating using a fired heater;
- oil dewatering using an electrostatic coalescer;
- test separation;
- produced water clean-up using hydrocyclones;

- a single train of two stage flash gas compression driven by electric motors;
- a single train of two stage gas injection compression, each stage driven by a gas turbine;
- gas dehydration by glycol contact;
- process cooling using a closed circuit cooling medium system;
- power generation using gas turbines; and
- flaring for emergencies only.

Pigging

The topside facilities will include provision for launching and receiving operational pigs. The facilities will be configured so that pigs can be launched down and received from all production and production/test risers entering the turret.

Layout

Topside layout is to be reviewed and is subject to change during the detailed design process.

The equipment will be arranged in skids. Each process or utility subsystem will be largely self-contained within a skid so that hook-up may be minimised and to enable a maximum degree of at-shore commissioning.

It is anticipated that the layout will be based around a central piperack (sections of the piperack are fabricated on each skid) and hook-up between skids will be at the piperack only.

2.4.1.3 Process Utility Support Systems

The following topsides utilities systems will be required to support the process systems.

Produced Water Treatment

All produced water will be treated prior to disposal overboard. All produced water disposed of overboard will meet the requirements of the C-NOPB Offshore Waste Treatment Guidelines. This primarily requires produced water to be treated to reduce oil concentrations of dispersed oil to the following levels:

- 40 mg/L or less as averaged over a 30-day period; and
- 80 mg/L or less over any 48-hour period.

The feasibility of using produced water to meet water injection requirements will be investigated during the detailed design process as well as the feasibility of re-injecting all produced water rather than discharging overboard.

Water injection requirements will be met by treating and injecting seawater. Facilities for deoxygenating, filtering and preventing bacterial growth will be included in the topsides.

Cooling Medium

A cooling medium system, whereby the cooling medium is circulated in a closed loop and is itself cooled by seawater, is proposed for the present evaluations.

A tri-ethylene glycol/water solution is proposed for the cooling medium. The cooling medium will be cooled in a plate exchanger.

Heating Medium

Heating medium will be required for the crude heater and the test heater. The possible requirement for production heating to prevent wax formation in the separators will be quantified following confirmation of the wax formation temperature.

Seawater Lift and Injection

Seawater will be required for injection into the reservoir to maintain reservoir pressure and also to cool the cooling medium. It is anticipated that seawater will be lifted by three lift pumps (two operating and one spare).

It is anticipated that the seawater will be filtered to approximately 100 micron in coarse filters and dosed with sodium hypochlorite to prevent marine growth in the formation. The hypochlorite will be generated by electrolysis of seawater. Final filtration levels will be determined once the reservoir filtration requirements have been determined.

It is expected that the seawater will be de-aerated prior to injection to prevent corrosion in the injection wells and possibly the injection water flowline. The de-aeration system will be either the conventional vacuum de-aeration type or a catalytic system. This will be evaluated at a later stage in the project development.

Fuel Gas

Fuel gas will be required for the gas turbine (if electrical drivers not chosen), for the main power generators, inert gas system and for the heating medium fired heater and steam boilers. Small quantities are used for flushing, blanketing, flare pilots etc.

It is anticipated that fuel gas will be taken from the discharge of the 1st Stage Injection Gas Compressor, filtered, heated and then let down to the fuel gas system pressure (assumed to be 3,000 kPa, depending on turbine selection). The fuel gas knockout drum will act as an accumulator to allow the main generator turbines to change to diesel fuel if fuel gas pressure is lost.

Flare and Vent System

There will normally be no continuous flaring. The largest continuous flaring load is likely to be the flash gas which may be flared at start up, and which will be within the flaring consent limits if the Flash Gas Compression System fails.

Flaring will normally only occur during non-steady state or emergency conditions. The largest relief load will be the gas injection compressor blocked discharge when $7 \times 10^6 m^3/d$ may have to be flared.

During design, measures will be evaluated to reduce atmospheric emissions wherever possible. The use of fuel gas and reinjection of produced gas are two of the means that will be employed.

Drain Systems

The vessel will be provided with three separate drain systems to handle the three different types of fluid. The hazardous drainage liquids from process equipment and piping will be carried in closed drains for recycling through the second-stage separator and produced water treatment system. Water subject to contamination from hydrocarbons around equipment will be collected in open drains and conveyed to the oily water sump tank. Other routine drainage from precipitation or washdown operations will be collected in open drains and discharged overboard in accordance with C-NOPB Offshore Waste Treatment Guidelines.

Oily Water Treatment

In the case of open drains for areas around, or containing, process equipment, the liquids will be collected and piped into an oily water sump tank. Oil will be skimmed from these sumps and pumped into a reclaimed oil sump. The clear water remaining will be discharged overboard in accordance with C-NOPB Offshore Waste Treatment Guidelines. Closed drain liquids will be routed to a closed drain flash drum. Oil from the closed drain flash tank will be routed to the reclaimed oil sump. The oil accumulated in the reclaimed oil sump will be pumped to the inlet of the medium pressure production separator.

Chemical Injection

The following chemicals may be required for normal production operations:

- methanol;
- corrosion inhibitor;
- demulsifier;
- wax inhibitor;
- scale inhibitor;
- oxygen scavenger;
- antifoam;
- biocide;
- asphaltine inhibitors;
- hypochlorite;
- polyelectrolyte; and
- hydrogen sulphide scavengers.

Chemical injection requirements will be determined during the design phase and adjusted based on actual production performance.

Potable and Service Water

Potable water will be primarily supplied from supply boats. Freshwater generators are planned to be installed for the back-up provision of potable water. Regular service water for washdown services will be seawater provided by a service water system.

Fire Water

Fire protection for the facility will be provided by a fire water system. The system will be designed such that it will incorporate appropriate back-up means of operation. A water fog system will be provided for the protection of vessel machinery spaces.

Jet Fuel

Helicopter fuel storage and pumping facilities will be installed.

Diesel

To maintain operability of systems during shutdown periods when fuel gas is not available, a backup diesel storage and distribution system will be provided for supply of fuel to the power generation system.

Compressed Air

Utility air and air for instrument operation will be provided by a compressed air system.

Inert Gas

Gas blanket requirements for crude oil storage tanks will be met by installing an inert gas system. A nitrogen system will be provided for flushing and inerting purposes.

Hydraulic Power

Hydraulic power may be provided by the installation of a central hydraulic storage, pumping and distribution system. This will provide high pressure hydraulic fluid to all points where such service is required.

De-icing

If required, de-icing of the superstructure will be accomplished by heat tracing and steaming facilities. Chemicals may be used for de-icing in certain circumstances.

2.4.1.4 Safety and Control Systems

Personnel safety will be paramount in the design of the facilities. This will apply to layout, construction and the provision of safety systems, which will include:

- emergency shutdown valves;
- flare and blowdown;
- hazardous drain system;
- fire and gas detection;
- active and passive fire protection; and
- personnel escape routes, temporary safe refuge and evacuation.

A safety shutdown system will be implemented for the protection of personnel, environment and equipment from accidental or aberrant operating conditions. This will isolate equipment or systems which may be detrimental to safety in the abnormal operating condition that has arisen. Several shutdown levels corresponding to various conditions are foreseen. Examples are as follows:

- Level 1: Abandon Platform Shutdown;
- Level 2: Emergency Shutdown;
- Level 3: Process Shutdown;
- Level 4: Partial Process Shutdown; and
- Level 5: Unit Shutdown.

The system will include the control and process shutdown system, the fire and gas system and the emergency shutdown system. These will operate separately, but will have common supervisory operators via an integrated, network-based system. The operator consoles will be located in the central control room, alongside other control packages.

It is anticipated that twin escape routes will be provided below the process deck. Three sides of these will be protected by walls as protection from blast and fire, while the outboard side will be partially open to minimize the potential of smoke buildup. Temporary safe refuge areas will be provided and evacuation plans will be prepared.

In the event that an unsafe condition develops, the safety shutdown condition will be communicated by audio-visual alarms in the central control room and throughout the facility.

Safety valve actuators will be for use exclusively in safety shutdown conditions. They will not be used in routine operations. Emergency shutdown valves will be provided subsea and on the inlet manifold above the riser connectors to ensure isolation of the process facility.

Depressurization of the topside facilities and vessel systems will be done manually for all safety shutdown levels, except for Level 1 where depressurization will occur automatically.

The various areas will be classified in accordance with codes and regulations that will serve as a basis for the selection of electrical equipment and the control of ignition sources.

2.4.1.5 Power Generation

The generators will be sized to meet the electrical loads of the FPSO vessel, both for normal and emergency operation. They will be dual-fuelled, able to function on produced gas or diesel. As well, for security, there will be provision for further diesel-driven power generation for emergency.

It is anticipated that a power generation capacity of 15 MW will be required to service the electrical needs of all onboard equipment except for the FPSO's systems and crude offloading. It is expected that the latter will be supplied by the FPSO's electrical systems. The electrical load is assumed to be supplied by turbine driven generators.

2.4.2 Subsea Facilities

The subsea facilities for White Rose will include all equipment necessary for the safe and efficient operation and control of the subsea wells and transportation of production and injection fluids between the wells and the FPSO. Anticipated operations include but are not limited to:

- steady state production with and without gas lift;
- steady state water and gas injection;
- planned and emergency shutdown;
- start-up after shut down with and without gas lift;
- surface controlled subsurface safety valves (SCSSV) leak off tests;
- hydrate, scale and wax inhibition;
- well intervention and workover;
- well treatments (for example, squeeze);
- production and gas lift choke replacement;
- subsea control module replacement;
- tie-in future facilities and possible future prospects;
- flushing and round-trip pigging;emergency intervention/repair activities;
- ability to flush lines in case of iceberg encroachment;
- temporary and final field abandonment; and
- controlled and emergency disconnect of the Spider Buoy from the FPSO.

The subsea facilities include all wellhead completion equipment, trees, manifolding, flowlines, umbilicals, risers, seabed structures, control systems and all interfaces required to control and operate the facilities and associated test, installation, inspection and maintenance equipment. Wellhead equipment, trees and manifolding structures (templates or clusters) will be located in open glory holes for iceberg protection (Figure 2.4-2).

In general, the subsea facilities will be designed for diverless installation, operation, inspection and maintenance, and will be based on field proven designs wherever possible. The subsea facilities will be configured to allow production well testing to be performed by routing individual wells through a test flowline to the test separator on the FPSO. Whenever well testing is not ongoing, the test line will continue to be used for production to mitigate wax formation in the line. Facilities will also be provided to permit round trip pigging of the production and test lines from the FPSO. Two independent and tested barriers will be available in order to prevent discharge from the well.

2.4.2.1 Manifold Systems

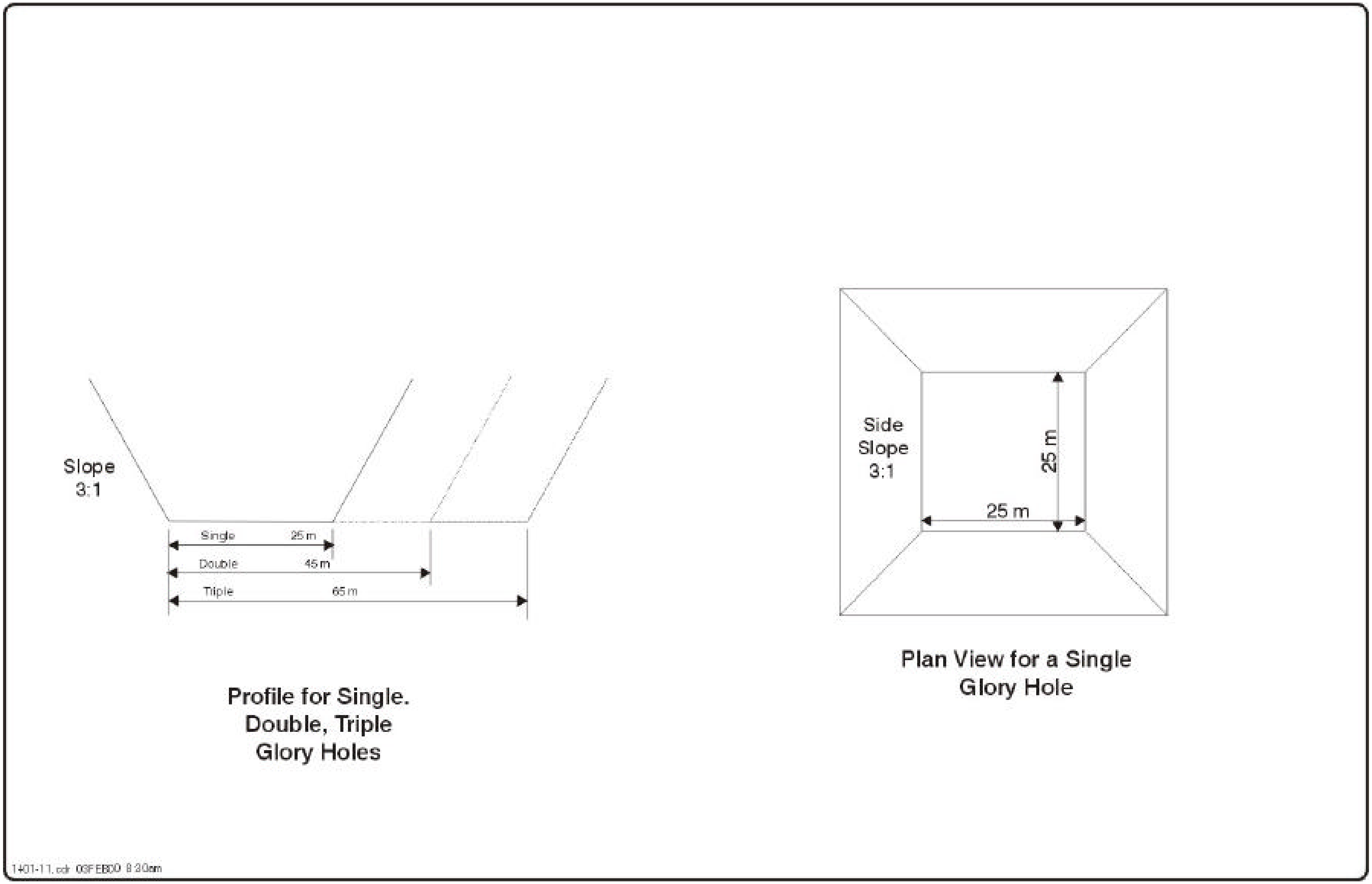
The subsea facilities will provide a means to co-mingle the flow from the subsea wells via a manifold. The manifold will be retrievable independently of the trees and provide sufficient flexibility to satisfy the operational requirements and also possible future expansion requirements.

Valving will be incorporated to allow for remote switching of flow between test and production headers.

Isolation will be incorporated into the design so that intervention on one tree or its choke valve(s) will not impede the normal operation of other wells connected to the same production/test/gas lift/injection header. In addition, where a tree connection is not used, provision will be made for installation of a pressure cap, which may remain exposed over extended periods.

To facilitate round trip pigging operations, a remotely actuated valve will be placed between test and production headers.

Figure 2.4–2 Typical Glory Hole Profile and Plan View



2.4.2.2 Subsea Control System

The subsea control system is presently expected to be an open loop, multiplexed electro-hydraulic system. The system will feature both subsea and FPSO located equipment. The level and location of the FPSO equipment will depend on overall field facility control philosophy, topsides equipment layout and turret design.

The subsea and FPSO located control equipment will be connected via electo-hydraulic control umbilicals.

The control system will be designed to supply sufficient hydraulic fluid (high pressure (HP) and low pressure (LP)) to control the remotely operated valves on the manifolds and christmas trees at all drill centres. Consideration will also be given to possible future expansion requirements. The system will also be designed to request, assimilate and transmit data from downhole, tree and manifold mounted instrumentation as required.

All subsea located equipment that is retrievable will be done by remotely operated vehicle (ROV) without the requirement for divers.

2.4.2.3 Subsea Control Umbilicals

The control umbilicals will be designed and manufactured to an appropriate industry standard with particular reference to API 17E.

They will convey HP and LP hydraulic fluids and chemical injection fluids and provide electrical cable paths from the FPSO to the subsea facilities. The requirement for spare cores within the umbilical is yet to be addressed.

The umbilicals will be fully compatible with the intended service duties (pressure, temperatures, control and chemical injection fluids, voltages and currents) without degradation for the design life. The umbilicals will also cater to any specific downhole or tree service operations as required.

Wherever possible, umbilicals will be a single continuous length. If this is not possible, the number of midline connections will be kept to a minimum.

The umbilicals will be comprised of static sections which will remain stable on the seabed under all operational and environmental loadings, and dynamic sections which will be designed to be compatible with the design of the dynamic risers and FPSO mooring lines.

2.4.2.4 Flowlines and Risers

The flowlines and risers for White Rose will be designed to an applicable industry standard (API 17J). They will provide an unobstructed flow conduit between the subsea facilities and the FPSO and will be fully compatible with the intended service duty for the entire design life. Appropriate valving will be installed subsea to control flows in both normal and emergency situations.

Design of the flowlines and risers will ensure that no maintenance is required during the design life other than external inspection using an ROV and damage repair and operational pigging. Flowlines will be designed to be stable on the seabed and risers designed to be compatible with the mooring lines and dynamic umbilicals. In addition, the risers will not be allowed to touch the seabed or break the sea surface other than is intended by design.

2.4.2.5 Insulation Requirements

The subsea facilities, including flowlines, will be insulated as required to meet the minimum arrival temperature at the top of the riser. This temperature will be the optimum temperature to satisfy both wax and hydrate formation criteria. Additionally, the selected hydrate and wax prevention strategy will be taken into account in order to ensure a safe and good practice in operation of the subsea system for both regular production and well testing scenarios. Insulation will also be designed to provide a minimum reasonable period for repair and restart in the event of an unplanned shut down, to minimize gelling of the crude in the lines.

2.4.2.6 Subsea Tie-in and Connection Systems

Initial field installation tie-ins and connections may be by either diver or diverless methods. Any connections that are required to be broken for maintenance and repair subsequent to initial installation will be by diverless methods. The final choice of tie-in and connection method will be made with due regard to safety, economic and feasibility considerations.

2.4.2.7 Iceberg Protection

The White Rose oilfield is subject to scouring icebergs and the design of the subsea facilities will consider the following:

- the location of wellheads, christmas trees and manifolds in glory holes with the top of the equipment a minimum of 2 to 3 m below the seabed level. This does not apply to components not critical to the integrity of the well;

- flowline trenching;
- rock backfilling;
- requirement for overtrawlability;
- design loads from fishing activities resulting from fishermen accidentally entering the safety zone;
- transfer of loads from icebergs to flowlines and umbilicals to ensure that well integrity is not compromised;
- design loads of snag and dropped objects; and
- flowline weak link technology.

In addition, the following inherent safety features will be built into the design of the subsea facilities:

- all subsea systems will be designed to be fail-safe (that is, all hydraulically operated isolation valves will automatically close if hydraulic power is lost); and
- any abnormal operating conditions resulting from control system damage, which endangers the safe operation of the subsea facilities, will trigger an automatic system shutdown.

2.4.2.8 Cathodic Protection

The subsea facilities will be protected from seawater corrosion for the life of the field by use of sacrificial anodes. Design of the protection system will be in accordance with an appropriate standard, for example DNV RP B401, but due consideration will be given to local conditions and regulatory requirements.

2.4.2.9 Oil Spill and Leak Protection

The goal in the design and operation of all subsea facilities will be to ensure that any possible iceberg impact will result in no pollution. The ice management system, will be in operation, and continuous monitoring of iceberg locations, drifts and forecast trajectories will be maintained during the iceberg season.

Provision will be made in the design for subsea oil production lines to be shut down and flushed, and for the FPSO to be disconnected from the subsea facilities in the event that a scouring iceberg enters the area.

Flowlines may be trenched to improve the thermodynamic characteristics, provide on-bottom stability and reduce the risk from scouring icebergs.

2.4.3 Export System

2.4.3.1 Offloading System

It is envisaged that the offloading facilities will be located at the stern of the FPSO and incorporate a fiscal metering system as an integrated package. The offloading hose will be of an appropriate length, circumference and specification. Storage facilities will be provided for the hose when not in use.

Design of the storage facilities and offloading system will ensure the crude remains above a temperature that will avoid problems associated with wax, including an appropriate safety margin.

The offloading system and offloading rate will be designed with regard to the environmental conditions in the field, such that the availability of the facility is not compromised by weather limitations which inhibit shuttle tanker connection or cause disconnection.

The offloading system will include a mooring hawser complete with messenger line, and all equipment necessary for handling and storing of the hawser. The tension in the hawser will be monitored continually while the shuttle tanker is connected and emergency disconnect will be provided.

Telemetry and communication systems necessary for both the safe approach/mooring of the shuttle tanker and control of the offloading operation will be provided on the FPSO.

2.4.3.2 Shuttle Tankers

Shuttle tankers will be used for exporting White Rose crude to markets in Eastern North America, the U.S. Gulf Coast or to a transshipment facility, such as the one currently operating at Whiffen Head.

Depending on the distance to market and on the volumes of crude to be exported, one to three tankers will be required. They will be sized appropriately for the transportation requirements and will be designed according to current relevant codes and standards, with due consideration of east coast environmental conditions. They will be bow-loading and capable of connecting to the FPSO offloading system in significant wave heights of 5 m.

2.5 CONSTRUCTION AND INSTALLATION

It is currently expected that all of the shorebased construction activities, including the FPSO, will take place in existing established facilities. It is therefore expected that all such facilities will be already set up to manage such environmental effects as emissions, effluent streams, or noise. Compliance with regulatory requirements will be the responsibility of the contractors or facility owners/operators of the site.

2.5.1 Steel FPSO

The FPSO will be a steel, ice-strengthened, ship-shaped vessel with a double hull. Topside facilities will be installed primarily on a horizontal plane raised above the level of the vessel deck. The vessel will be moored by a turret, which will remain geo-stationary while the vessel will be free to "weather vane" around it. A fluid swivel will convey the crude from the risers to the topside production facilities.

2.5.1.1 Construction Method

Historically, the hull and topsides have been built in separate facilities in different locations. This is expected to be the case for White Rose also.

A modular approach is normal for fabrication of the hull. The size of individual modules is dependent upon the lifting capacity available at the shipyard.

The turret is essentially a cylindrical vessel and the manufacturing and assembly practices for the turret are similar to those applicable to such vessels. Structural sections are pre-fabricated and assembled, either on the hull or separately for later lift into place.

The topside facilities are normally manufactured in pre-assembled units (PAUs), modules, or skids.

The hull and turret, topside facilities and all equipment are delivered to an at-shore assembly site for hook-up, mechanical completion and testing prior to proceeding to the production site.

2.5.2 Subsea Facilities

The following are the types of facilities that will be included in the subsea systems:

subsea trees;
production and injection risers;
riser base manifold;
field manifolds or templates;
flowlines; and
control systems and umbilicals.

2.5.2.1 Construction Methods

Flexible line production and injection risers, suitable for use in the harsh environment at White Rose, will be supplied by manufacturers using their proprietary manufacturing process. The risers are supplied fully equipped and tested, and ready to install.

Subsea manifolds and flowlines will gather the production and convey it to the risers. Manifolds include headers, piping, valves, and control equipment, mounted on a base.

Subsea wells will include the following:

- wellheads;
- casing hangers;
- hydraulic connectors;
- valve assemblies;
- guide frames;
- subsea trees;
- protective structures; and
- control systems.

Many proprietary well components will comprise high quality forgings requiring heat treatment, special welding procedures and precision machining. Tree installation will require special running and testing tools.

Flowlines will be either flexible or rigid steel pipe. Flexible flowlines will be prepared by the manufacturer, ready for installation. Rigid steel pipe will be manufactured by the mill in lengths appropriate to transportation and handling constraints, and the limitations of the lay barge. Consideration will be given to the option of installing the flowlines in cased bundles. In this case, the flowline bundle will be fabricated onshore at a suitable construction site. Another option which may be examined for steel pipe is welding them into long strings onshore and winding them on to spools on a reel lay vessel for offshore installation.

2.5.3 Installation

The following is a list of the types of installation activity that may occur offshore:

- piled seabed anchors for the FPSO;
- embedded anchors;
- riser bases and risers;

- intrafield flowlines;
- production manifolds and templates in glory holes; and
- single well ice protection systems.

These activities will occur over a fairly limited area. Their impacts will be localized and only very moderate volumes of excavation or sediment will be involved (refer to Part One, Section 4.3.1.3).

Onshore support will be required for installation of the FPSO and the subsea facilities.

Specific detailed safety and environmental issues related to the installation and commissioning work will be addressed prior to implementation of that work as part of the authorization process.

Environmental effects monitoring programs will be implemented at this stage of the project.

2.5.3.1 FPSO

The precise location for the FPSO will be marked by underwater beacons placed by site survey, or by other appropriate methods, prior to the arrival of the FPSO. Anchors and mooring lines will also be installed at the location in advance of the arrival of the FPSO.

Following construction, sea trials, and at-shore hook-up and commissioning, the FPSO will be brought to the site and secured to the mooring system.

2.5.3.2 Subsea Facilities

Depending on their size, manifolds may be installed either directly through the moonpool of a semi-submersible drilling unit or from the deck of a crane vessel with sufficient lifting capacity to lower them to the seafloor, where they could be picked up and placed by a drilling unit.

A dynamically positioned vessel, equipped for flexible pipe and cable installation, will be used to install the risers. Divers may be used for making the subsea connections. They would mobilize from a saturated diving spread on the vessel.

Wellheads will be installed in the glory holes through the moonpool of the drilling unit. Upon completion of the well-drilling operation, the drilling unit will also be used to install the christmas trees. Final connection of the wells to the manifolds by jumper spools will be carried out by divers.

Flowlines will be installed during the summer weather window.

If flexible flowlines are used, they can be spooled off a dynamically positioned lay vessel. If steel flowlines are used, they can be installed from a lay barge or a dynamically positioned reel vessel. For the towed bundle installation method, two tow vessels will be required, one for the actual forward tow and the other for the trailing end.

2.5.3.3 Onshore Support

The offshore installation activities will require onshore support for warehousing and wharfage, and for helicopter operations. These activities will be carried out at existing worksites.

2.5.4 Drilling Services

One or more semi-submersible drilling units will be used throughout the life of the field for drilling, re-entering and completing wells. These units will be leased.

The units will be moored at each well location by onboard chain and anchor-handling equipment. Marine support vessels, with anchor-handling capability, will also be deployed.

2.6 OPERATIONS AND MAINTENANCE

2.6.1 Organization

Husky Oil will manage the production and maintenance operations of the White Rose oilfield on behalf of itself and Petro-Canada from the Husky Oil office in St. John's, where the management team will be located. The day to day management and control of all offshore operations will be the responsibility of the Offshore Installation Manager (OIM) who will be located on the FPSO. Each MODU operating in the field will also be managed and controlled by an Installation Manager. The OIM on the FPSO will, however, take responsibility for routine coordination of all concurrent offshore operations.

2.6.1.1 FPSO

The crew complement for the FPSO is expected to be approximately 45 to 50 at any one time. Provision for rotation requires that this number be doubled, giving an FPSO staff strength of some 90 to 100 personnel.

There will be an occasional requirement for construction or other specialized personnel offshore to perform upgrades, repairs, or modifications to equipment or systems. The work to be performed by such personnel will normally be planned and scheduled for minimal impact on production. Where necessary, due to unforeseen circumstances arising offshore, they will be mobilized on an ad hoc basis. The numbers of such personnel will depend upon the scope of work to be performed. As far as possible, personnel already onboard as part of the Maintenance group will be used in support of such activities.

The offshore operation will be provided with engineering support by the Technical Services group. This support will be for specific tasks, or investigation and solution of process problems, and will be on an ad hoc basis.

2.6.1.2 MODU

Each drilling vessel will require some 70 to 100 drilling and support staff during drilling operations. To provide for rotation, this means a requirement of some 140 to 200 personnel per drilling unit.

2.6.2 Operations and Maintenance Procedures

Operations and maintenance procedures and manuals will be prepared specifically for the White Rose development. They will make provision for compliance with all regulatory requirements, and personnel will be trained to operate in accordance with the manuals and procedures.

2.6.2.1 Systems

Systems manuals will provide descriptions and drawings of the primary process, ancillary systems, and associated equipment and subsystems. The rationale behind the design will be presented. Operating parameters will be set out. Operator training manuals will be based upon these documents.

2.6.2.2 Equipment

Detailed information on each individual piece of equipment and each system and subsystem will be assembled and incorporated into data books. Such information will be drawn from vendor sources, design specifications and operational record. It will include drawings, specifications, descriptions, materials, installation guidelines, operation and maintenance guidelines, and recommendations on spare parts inventory.

2.6.2.3 Reporting Relationships and Procedures

Roles, limits of authority, lines of reporting and accountabilities in production operations will be set out in reporting procedures and where applicable bridging manuals. These will clearly identify reporting relationships throughout the organization as well as with external agencies.

The procedures for record-keeping will be set out in the manuals, together with requirements for report generation and distribution and data acquisition.

Operating and maintenance records will be documented as required by Husky Oil and governing regulations. Requisite reports will be produced routinely.

2.6.2.4 Maintenance Procedures

Maintenance procedures manuals will be prepared for all equipment. These procedures will be based on design data, recommendations by vendors, operating conditions, and the importance of the equipment to operation of the facility. This latter aspect will be based on the effect of failure of the item of equipment on personnel safety, environmental consequences, operational efficiency, and revenues.

The maintenance program will be extensively supported by computerized systems, providing detailed information on each item of equipment, including its criticality, maintenance history, and spares to be kept in inventory. The system will also be linked to an inventory control system.

The basic significant features of monitoring, inspection, and maintenance and repair, will be recognized in the program.

Monitoring

All structures and equipment will be monitored routinely as a planned part of the maintenance program. Sensors and monitoring devices will be used as part of the program. Also as part of the overall monitoring program, the integrity of the following aspects of the FPSO will be monitored, using on line monitoring systems:

- structural components;
- sub-structural components;
- equipment condition;
- corrosion rates; and
- vessel stability.

Inspection

All structural elements, piping and equipment will be inspected regularly and comprehensively to ensure their integrity. The degree of inspection will be predicated upon the item's criticality to the operation, its vulnerability and service, operating conditions, vendor recommendations, and feedback from the monitoring systems.

Inspection will be accomplished by one or more of the recognized techniques of visual inspection, non-destructive testing, operational parameter monitoring, vibration monitoring, and field and laboratory tests.

The main areas of attention will be:

- life saving equipment;
- structural;
- pressure containing systems;
- rotating equipment;
- subsea systems; and
- lifting equipment.

Maintenance and Repair

The focus of this activity is to maintain the facility in optimum condition to ensure safe and continuous production operations. Three categories of maintenance and repair are recognized:

- preventative maintenance;
- predictive maintenance; and
- breakdown maintenance.

How a particular piece of equipment is categorized depends on its criticality to production (for example, safety equipment and systems will be in the top category), and every effort will be made to avoid incurring situations where these have to receive maintenance on a breakdown basis.

The procedures will also cover the monitoring and control of ice build-up on the various structural components of the FPSO.

The maintenance and repair program will be supported by a computerized support system which will record maintenance history, maintenance costs, item availability, and breakdown frequency.

2.6.2.5 Production and Marine Procedures

This procedures manual will deal with the safe and efficient operation of the FPSO for all facets of production and marine-related activities. It will describe in detail how the following will be carried out or managed:

- process start-up and shutdown;
- routine production;
- operations limits;
- adverse weather conditions;
- crude storage and shipment; and
- marine activities.

2.6.2.6 Ice Management Procedures

Husky Oil already has an Ice Management Plan in place for its exploration operations on the Grand Banks. Husky Oil will review and update, or modify, this plan as appropriate for application to the production phase of the White Rose development.

Ice management procedures will set out clearly the steps and responsibilities for ice surveillance, monitoring and reporting. The procedures will be structured to include cooperation with other operators and government agencies in their concurrent ice surveillance and management operations on the Grand Banks. All available ice intelligence information sources will be used to ensure the well-being of the facilities offshore.

The steps necessary for avoidance of iceberg collision or excessive sea ice pressure will be detailed in the procedures. This will include how the following will be accomplished:

- disconnection of production risers;
- disconnection and flushing of loading lines; and
- repositioning of the FPSO.

2.6.2.7 Health, Safety and Environment (HSE) Management System

Husky Oil will implement a health, safety and environment management system for the White Rose development that will meet or exceed all statutory requirements, and facilitate continued employee safety and health as well as environmental protection. An overview of this system is outlined in Part One, Chapter 8.

2.6.2.8 Emergency Procedures

Procedures will be implemented to address every kind and scale of emergency that might reasonably be expected to arise on the FPSO or other offshore facilities. A review of the contingency plans is included in Part One, Chapter 6.

2.6.3 Operational Limits

The limiting conditions imposed by environmental factors on the structure and associated systems will be largely predicated upon the final design criteria adopted for the FPSO and equipment specification.

Environmental factors could impose limitations on the following operations:

- station-keeping ability;
- deck loading;
- bulk storage;
- crane operation;
- helicopter movement;
- ice management; and
- crude storage and tanker loading.

The South White Rose facility is expected to have a system efficiency in the range of 90 to 94 percent and operating efficiency will be subject to equipment, reservoir and well performance as well as environmental factors. This is consistent with experience on similar operating facilities in the North Sea and elsewhere.

2.6.4 Logistics

2.6.4.1 Marine Base, Warehousing, and Storage Yard

The marine base will be located in or near St. John's. The wharfage should be capable of servicing two to three supply vessels concurrently. Synergies with other East Coast operators will be investigated. The warehouse and pipeyard will preferably be located at, or close to, the marine base.

The base will require sufficient handling equipment in cranes, forklifts and winches to support the three vessel loading/offloading operation. It must similarly also be capable of handling the bulk materials, mud, cement, fuel, and water for up to three vessels concurrently.

2.6.4.2 Support Vessels

The number and range of support vessels required will be determined after the complete design of the offshore facilities and will be leased from experienced marine contractors. Vessels will be required for two primary purposes:

- support services on location; and
- transportation between the marine base and offshore facilities.

The support services on location will cover:

- anchor and mooring-chain handling;
- iceberg surveillance, towing and deflection;
- shuttle tanker mooring assistance;
- environmental monitoring;
- oil spill response;
- diving support;
- subsea inspection and maintenance;
- standby service:
- person-overboard;
- on-scene command;
- search and rescue; and
- emergency evacuation.

Transportation services between the marine base and offshore facilities will require:

- cargo and bulk re-supply; and
- personnel transportation (marine).

Fleet configuration will be finalized after completion of the field depletion plan and design engineering for the FPSO. Vessels will be continuously available in the field for standby duty in accordance with regulatory requirements. Supply vessels will convey materials, consumables and equipment to and from the offshore facilities.

All personnel staffing the support vessels will be fully trained in emergency duties. There will be routinely scheduled emergency drills and exercises.

2.6.4.3 Personnel Movements

Personnel movements between St. John's and the field will normally be carried out by helicopter. It is expected that a fleet of one to two helicopters will be sufficient to meet the needs of conveying the approximately 500 (250 offshore at any one time) production, drilling, and support personnel to and from St. John's and the respective offshore facilities. This is based on a scenario which includes ongoing production in conjunction with two drilling units operating concurrently.

Husky Oil intends to investigate the potential benefits of cooperation with other operators in this regard.

2.6.5 Communications

Communications includes all systems, both internal and external, that transmit voice, data, video or image information. Husky Oil will require such communications linkages between all of its facilities both onshore and offshore on the White Rose project.

System reliability will be paramount for the safety of all offshore operation. Primary and back-up systems will be used to ensure continuous communications capability amongst all facilities in all environmental conditions.

The system components will be state-of-the-art, multi channel and will have adequate redundancy for their purpose. The actual configuration will be finalized at a later date, but is expected to based on the system currently in use by Husky Oil. The system will comprise the following elements:

- FPSO and MODU/Shore Link;
- Telephone System;
- Local Area Network (LAN);
- Ship Radio System;
- Air/Ground/Air VHF Base Station;
- Air/Ground/Air VHF Hand-held Radios;
- Non-directional Beacon for Aircraft Approach;
- VHF Radio System; and
- Shore Base Radio Station Services (including marine vessel tracking and flight following).

2.7 DECOMMISSIONING AND ABANDONMENT

At the end of the production life of the White Rose oilfield, Husky Oil will decommission and abandon the site according to C-NOPB requirements and *Newfoundland Offshore Petroleum Production and Conservation*

Regulations and any other applicable laws. Floating production facilities will be removed from the field. Subsea infrastructure will be removed or abandoned and the wells will be plugged and abandoned. Buried flowlines will be abandoned *insitu*, after flushing.

The site will be restored to a condition that minimizes residual environmental impact and permits reinstatement of fishing in the area and unimpeded navigation through it. Nothing will be left on the seafloor to pose a threat to the fishing industry.

2.7.1 Approval Process

At the completion of oil production from the White Rose field, Husky Oil will seek approval to decommission the facilities and abandon the field in accordance with the requirements of the *Newfoundland Offshore Petroleum Production and Conservation Regulations*.

The approval request will include all relevant data required to demonstrate that all practical and economic extraction of oil from the field has been achieved.

2.7.2 Abandonment Methods

2.7.2.1 Production and Injection Wells

Husky Oil intends to follow the following procedure for abandonment of wells:

- install cement plugs and mechanical bridge plugs as follows:
  - at the bottom of the deepest casing string;
  - above the uppermost perforations;
  - at depths not exceeding 150 m below the mudline;
  - to seal off porous, permeable formations; and
  - to seal off formations with abnormal pressures;
- remove wellheads and cutting casings; and,
- displace hydrocarbons in production wells with a kill fluid and abandon in place.

2.7.2.2 FPSO

At abandonment, the FPSO will be disconnected from the risers. The topsides equipment will be decommissioned offshore, and any residual hazardous waste arising from this will be taken to shore and treated at appropriate approved waste treatment facilities. All anchors, lines and chains will be recovered.

The ultimate disposition of the FPSO will depend upon its condition at of the end of the production life of the White Rose field, and upon the options available for further use.

2.7.2.3 Subsea Facilities

All equipment located in glory holes will be removed and the glory holes will be left as they are. Christmas trees and manifolds will be purged, rendered safe, and recovered.

Trenched flowlines will be flushed and left *insitu* below the seafloor.

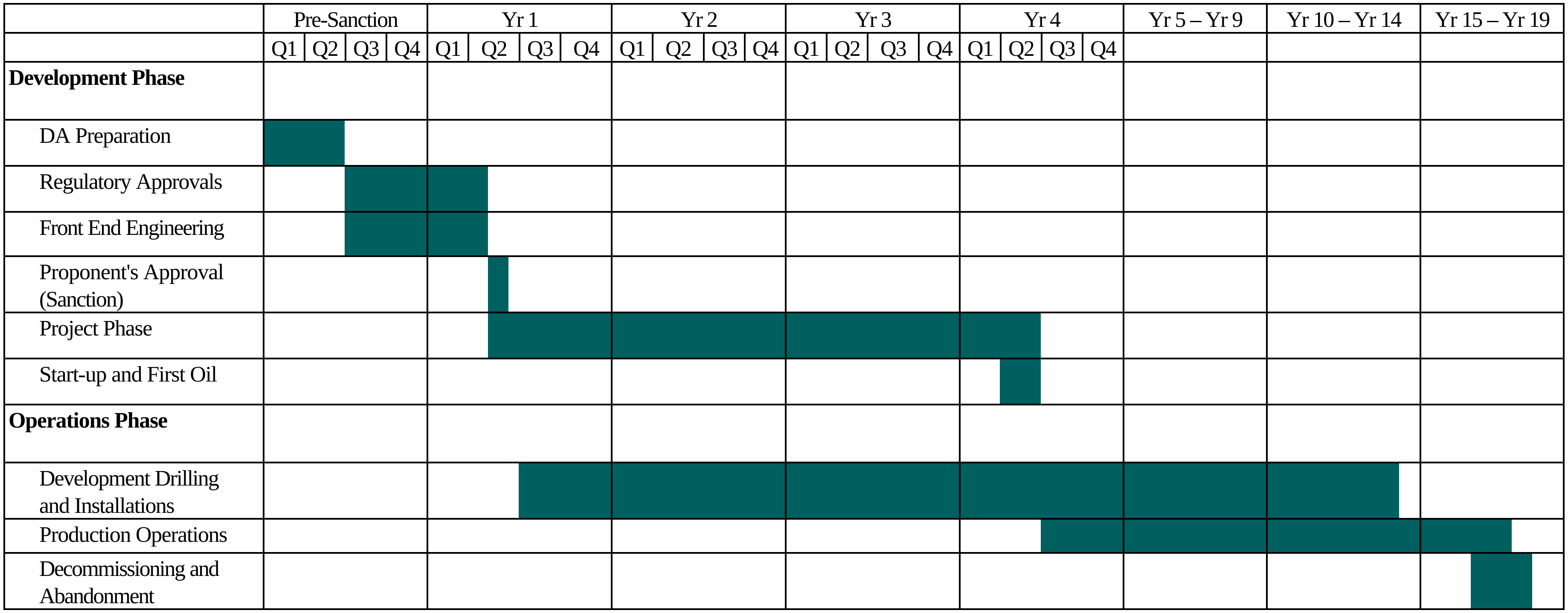
All other subsea facilities above the seafloor, including production manifolds, riser base manifolds, loading riser manifolds, short connector flowlines, and export lines, will be purged and decommissioned in accordance with regulations prevailing at the time.

All risers and umbilicals will be decommissioned, rendered safe, and recovered.

2.8 SCHEDULE

A project development schedule is provided in Figure 2.8-1.

Figure 2.8–1 Project Development Schedule



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Appendix 1.A

Issue Scoping Document

1. Purpose

This document provides scoping information for the environmental assessment of the proposed White Rose petroleum production project. The proposed project location is on the Grand Banks offshore Newfoundland, approximately 350 kilometres east of St. John's. Husky Oil Operations Limited (Husky), as operator for the White Rose field, represents the project proponents.

Included in this document is a description of the scope of the project that will be assessed, the factors to be considered in the assessment, and the scope of those factors.

The document has been developed by the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) in consultation with the Department of Fisheries and Oceans (DFO), Environment Canada (EC), Industry Canada (IC) and C-NOPB's other advisory agencies in the Governments of Canada and of Newfoundland and Labrador[1]. The C-NOPB also considered environmentally related comments that were documented by Husky between late 1999 and May 2000, during its public consultation process.

2. Regulatory Considerations

The White Rose project is subject to the provisions of the *Canada-Newfoundland Atlantic Accord Implementation Act* and the *Canada-Newfoundland Atlantic Accord Implementation Newfoundland Act* (the Accord Acts). The Accord Acts require that prior to production from a pool or field, the operator of the pool or field must hold a valid production licence and that an approved Development Plan be in place. Approval of the Development Plan includes consideration of matters relating to the safety of operations, protection of the environment, and conservation of the petroleum resource. Approval of a Canada-Newfoundland Benefits Plan is a statutory pre-condition to approval of the Development Plan.

Husky has indicated that it plans to submit its development application, comprising a Development Plan, an Environmental Impact Statement (EIS), a Socio-Economic Impact Statement (SEIS) and a Canada-Newfoundland Benefits Plan, to the C-NOPB in late July 2000. The C-NOPB intends to appoint a Commissioner under Section 44 of the Accord Acts to conduct public hearings on the development application. The Commissioner will be empowered to receive comments from the public concerning any matters associated with the development application.

[1] Appendix 1 contains a list of the departments and agencies consulted during the preparation of the document.

The White Rose project also is subject to the *Canadian Environmental Assessment Act* (CEAA). The C-NOPB must issue a production licence respecting the project, and thereby "has the administration of federal lands and . . . disposes of those lands or any interests in those lands . . .for the purpose of enabling the project to be carried out" within the meaning of paragraph 5(1)(c) of CEAA. The C-NOPB therefore requires an environmental assessment under CEAA, and is a "responsible authority" respecting the project.

The Department of Fisheries and Oceans (DFO) has determined that the project will result in the harmful alteration, disruption or destruction of fish habitat and thereby require an Authorization for Works or Undertakings Affecting Fish Habitat under Section 35(2) of the *Fisheries Act*. As Section 35(2) authorization requirement is a law list trigger under CEAA, the DFO is also a Responsible Authority with respect to the environmental assessment of the proposed project. Further, as a condition of this authorization, the proponent will be required to develop a fish habitat compensation plan that will be used by DFO in the development of a compensation agreement to compensate for losses of productive fish habitat in accordance with DFO's *Policy for the Management of Fish Habitat*.

Similarly, Environment Canada (EC) has determined that the construction of glory holes during the project and the deposition of spoils upon the surrounding seabed likely will require a Disposal at Sea Permit under the *Canadian Environmental Protection Act*, and that EC is a responsible authority. Finally, Industry Canada (IC) has determined that the radio equipment on the production installation will require its approval pursuant to Section 5 (1)(f) of the *Radiocommunications Act*, and that therefore it is a responsible authority respecting the proposed project as well. The project is subject to a "comprehensive study" level of assessment under CEAA since it falls within the *Comprehensive Study List Regulations,* Part IV, Oil and Gas Projects, Section 11.

The C-NOPB will be the "lead responsible authority" respecting the assessment and in this role will be responsible for coordinating the review activities of the other responsible authorities as well as those of other expert government departments and agencies that participate in the review.

> ***The C-NOPB, DFO, EC and IC intend that the environmental impact statement submitted with the development application, together with such supporting documents as may be necessary, will fulfill the requirements for a "comprehensive study report" (CSR) pursuant to the CEAA, and pursuant to Section 17 (1) of the CEAA, formally delegate the responsibility for preparation of an acceptable CSR to Husky Oil Operations Limited, the project proponent.***

3. Scope of the Project

The project to be assessed consists of the following components:

3.1 Construction, installation, operation, maintenance, modification, decommissioning and abandonment of a petroleum production facility respecting the White Rose field, as described in the *White Rose Oilfield Project Description* prepared by Husky and dated March 17, 2000[2];

3.2 Construction, installation, operation, maintenance, modification, decommissioning and abandonment of subsea facilities associated with the White Rose field, including drilling and workover of development wells, subsea flow lines and any related seabed trenching, excavation, covering and/or spoil deposition;

3.3 Operation of support craft associated with the above facilities, including but not limited to mobile offshore drilling units, platform supply and standby vessels and helicopters, and shuttle tanker activity that is incremental to that already in existence or expected to be in existence; and

3.4 Any new onshore facilities that are expected to be required to support the above activities.

4. Factors to be Considered

The environmental assessment shall include a consideration of the following factors in accordance with Section 16 of CEAA. :

4.1 The purpose of the project;

4.2 The need for the project;

4.3 Alternatives to the project;

4.4 Alternative means of carrying out the project which are technically and economically feasible and the environmental effects of any such alternative means;

4.5 The environmental effects[3] of the Project, including those due to malfunctions or accidents that may be reasonably expected to occur in connection with the project;

[2] The Project Description may be viewed on the White Rose Web site at www.huskywhiterose.com
[3] The term "environmental effects" is defined in Section 2 of the CEAA.

4.6 Cumulative environmental effects of the Project that are likely to result from the project in combination with other projects or activities that have been or will be carried out;

4.7 The significance of the environmental effects described in 4.5 and 4.6;

4.8 Measures, including contingency and compensation measures as appropriate, that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project;

4.9 The significance of adverse environmental effects following the employment of mitigative measures, including the feasibility of additional or augmented mitigative measures;

4.10 The capacity of renewable resources that are likely to be significantly affected by the project to meet the needs of the present and those of the future;

4.11 The need for, and the requirements of, any follow-up programs in respect of the project; and

4.12 Comments from the public respecting any of the matters described above that are received in accordance with CEAA and its regulations.

5. Scope of the Factors to be Considered

Husky Oil Operations Limited will prepare and submit to the C-NOPB an environmental assessment for the above described physical works and activities. The environmental assessment will address the factors listed above, as well as the matters listed in the appropriate sections of the 1988 C-NOPB *Development Application Guidelines,* and issues and concerns identified and documented by Husky through regulatory, stakeholder, and public consultation.

It is understood that the proponent will be using the “valued ecosystem component” (VEC) approach to focus its analysis. A definition of each VEC (including components or subsets thereof) identified for the purposes of environmental assessment, and the rationale for its selection, shall be provided.

The environmental assessment will consider the potential effects of the proposed physical works and physical activities within spatial and temporal boundaries that encompass the periods and areas during and within which the project may potentially interact with, and have an effect on, one or more VEC. These boundaries may vary with each VEC and the factors considered, and should reflect a consideration of:

- the construction, operation, maintenance, and decommissioning phases of the proposed physical works and/or physical activities;

- the natural variation of a VEC or subset thereof;

- the timing of sensitive life cycle phases in relation to the scheduling of proposed physical works and/or physical activities;

- interrelationships/interactions between and within VECs;

- the time required for recovery from an effect and/or return to a pre-effect condition, including the estimated proportion, level, or amount of recovery;

- the area within which a VEC functions and within which a project effect may be felt.

The assessment of cumulative environmental effects should be consistent with the principles described in the February 1999 CEAA *Cumulative Effects Assessment Practitioners Guide* and in the March 1999 CEAA operational policy statement *Addressing Cumulative Environmental Effects under the Canadian Environmental Assessment Act*, and will include a consideration of environmental effects that are likely to result from the proposed project in combination with other projects or activities that have been or will be carried out (*i.e.*, other projects or activities for which formal plans or applications have been made). These other projects should include, but not necessarily be limited to, the following:

- fishing activities;
- (for marine birds) hunting activities;
- marine transportation activities;
- the Hibernia project;
- the Terra Nova project; and
- petroleum exploration activity that either has been approved or whose approval has been applied for, or equivalently a level and scale of activity reasonably predictable from a consideration of recent historical activity and present offshore land holdings.

The scope of the factors to be considered in the environmental assessment pursuant to the CEAA will include the components identified in the Summary of Potential Issues provided in Section 5.3, setting out the specific matters to be considered in assessing the environmental effects of the project and in developing environmental plans for the project, and the spatial boundaries identified in Section 5.1. Considerations relating to definition of “significance” of environmental effects are provided in Section 5.2.

5.1 Spatial Boundaries

The proponent shall clearly define, and provide the rationale for the spatial boundaries that are used in its environmental assessment. Boundaries should be flexible and adaptive to enable adjustment or alteration based on field data and/or modelling results. A suggested categorization of boundaries follows.

Project area	The area directly disturbed, altered or destroyed by construction, installation, operation, decommissioning and related activities, including associated physical works (i.e., locations of glory holes and/or caisson wells, production installation and its moorings, drilling unit moorings, subsea flowlines) and any vessel and/or fishery exclusion zones that may be established.
Affected area	The area which could potentially be affected by project activities beyond the project area, including associated physical works and activities. The "affected area" boundary varies with the component being considered (e.g., for assessment of the effects of routine drilling discharges, the area calculated, modelled or otherwise estimated to be affected would be included within this boundary).
Region	The area extending beyond the "affected area" boundary. The "region" boundary will also vary with the component being considered (e.g., boundaries suggested by bathymetric and/or oceanographic considerations).
Provincial	The area extending beyond the "region" boundary but confined to the Province of Newfoundland and Labrador, the area of jurisdiction of the C-NOPB, or both.
National	Areas of Canadian jurisdiction (including exclusive economic zone and continental shelf) outside the "provincial" area.
Transboundary	The area outside Canada's jurisdiction.

5.2 Significance of Adverse Environmental Effects

The Proponent shall clearly describe the criteria by which it proposes to define the "significance" of any adverse effects that are predicted by the environmental assessment. This definition should be consistent with the November 1994 CEAA reference guide *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects*, and be relevant to consideration of each VEC (including components or subsets thereof) that is identified.

5.3 Summary of Potential Issues

Issues to be considered in the environmental assessment will include generally the matters listed in the appropriate sections of the 1988 C-NOPB *Development Application Guidelines*, as well as issues and concerns that pertain to environmental effects and are identified and documented by Husky through regulatory, stakeholder, and public consultation. These issues should include, but not necessarily be limited to, the following:

General

5.3.1 The methodology that the Proponent uses to assess environmental effects;

5.3.2 Identification where possible of testable hypotheses associated with the results of the assessment;

Air Quality

5.3.3 Air emissions associated with project activities, including annual estimates of emissions of sulphur dioxide, nitrous oxides, particulate matter, hydrocarbons and carbon monoxide and any implications for health and safety of workers that may be exposed to them;

5.3.4 "Greenhouse gas" emissions associated with project activities, including annual estimates of these emissions and a description of potential means for their reduction and reporting;

Marine Resources

5.3.5 Characterization, including quantification to the degree possible, of the spatial area of seabed that is predicted to be affected by dredging, trenching and dredge spoil disposal, drill cuttings and other discharges;

5.3.6 Marine and/or migratory birds using the Grand Banks:

- spatial and temporal species distributions
- species habitat, feeding, breeding, and migratory characteristics of relevance to the environmental assessment;
- particularly sensitive (e.g., "threatened", "endangered" etc.) species;
- potential attraction to lights, flaring and/or domestic wastes associated with project structures;
- potential for bioaccumulation by birds of heavy metals associated with project discharges;
- effects of project-related aircraft overflights upon bird concentrations and/or colonies;
- effects of oil spills of all sizes, as well as any "sheens" that may be associated with regulated discharges;
- means by which bird mortalities associated with project operations may be documented and assessed;
- means by which potentially significant effects upon birds may be mitigated through design and/or operational procedures

5.3.7 Marine fish, shellfish, reptiles and marine mammals, and their respective benthic and water-column habitat:

- characterization of existing environment in the project area, affected area and region;
- Distribution and abundance of species utilizing the project, affected area and region with consideration of life stages (e.g., spawning areas, overwintering, juvenile distribution, migration, feeding areas, prey requirements, relative abundance, benthos, diversity);
- Description to the extent possible of location, type, diversity and areal extent of marine fish habitat in the project and affected areas, in particular those indirectly or directly supporting traditional, historical, present or potential fishing activity, and including any critical (e.g. spawning, feeding, overwintering) habitats;
- environmental effects due to the project, including cumulative effects, with consideration of lethal and sublethal effects, species interrelationships, fish health and productivity and a quantification of affected habitat;

Marine Use

5.3.8 Presence of structures and/or operations:

- size and location of temporary or project-life exclusion zones;
- description of project-related traffic, including routings, volumes, scheduling and vessel types;
- effects upon access to fishing grounds;
- effects upon general marine traffic/navigation, including research surveys;

- cumulative effects when combined with those of other developments

5.3.9 Traditional, existing and potential commercial, recreational and aboriginal/subsistence fisheries, including foreign fisheries:

- consideration of underutilized species and species under moratoria;
- consideration of the traditional fishery and the changing nature of the fishery;
- effects of project operations and accidental events upon the foregoing, including potential reopening of fisheries currently under moratoria;
- effects due to real or perceived fish/shellfish taint;
- cumulative effects when combined with other developments;

Discharges and Emissions

5.3.10 Effects of electromagnetic emissions from radio equipment upon personnel safety and means of mitigation/elimination;

5.3.11 Planned project discharges to the marine environment:

- dredge spoil, drilling fluids and cuttings, produced water, bilge water, “grey” water, “black” water, cooling water, deck drainage;
- characterization, quantification and modelling of expected discharges (e.g., concentration of metals, nutrients, hydrocarbons, biocides, etc., timing of discharges), including a description of the models employed;
- means for reduction, re-use and recovery of wastes beyond those specified in regulations and guidelines, including a description of “best available/practicable technology”;
- assessment of technical and economic feasibility of subsurface re-injection of produced water and of drill cuttings associated with organic –phase drilling fluids;

Accidental Events

5.3.12 Quantification of blowout risk;

5.3.13 Quantification of risk of oil spills of all volumes associated with the project;

5.3.14 Modelled physical fate of oil spills, including descriptions of models and/or analyses that are employed and the physical data upon which they are based;

5.3.15 Environmental effects of oil or chemical spills;

5.3.16 Cumulative effects in consideration of "chronic" oil pollution on the Grand Banks (e.g. spills from other offshore operations, bilge dumping and other discharges from vessels);

5.3.17 Effectiveness of spill countermeasures;

Physical Environment

5.3.18 Meteorological, oceanographic and seabed characteristics of project area and region, including extreme conditions;

5.3.19 Site-specific sea ice and iceberg conditions, including iceberg scour of the seabed;

5.3.20 Physical environmental monitoring, observation and forecasting programs that will be in place during the project;

5.3.21 Ice management/mitigation procedures, including criteria respecting disconnection of project installations and assessment of the efficiency of detection and deflection techniques;

Environmental Management

5.3.22 Proponent's/Project environmental management system and its components, including:

- pollution prevention policies and procedures;
- environmental effects monitoring programs (see below);
- environmental compliance monitoring;
- provisions for management system auditing;
- environmentally-related training for project employees and contractors, including project vessels;
- chemical selection and management procedures;
- fisheries liaison/interaction policies and procedures
- program(s) for compensation of affected parties, including fisheries interests, for accidental damage resulting from project activities

5.3.23 Provision of an acceptable fish habitat compensation strategy, including options considered, in accordance with the Department of Fisheries and Oceans *Policy for the Management of Fish Habitat*.

5.3.24 Emergency response plans, including:

- risk-based determination of oil spill response needs, including those for small-volume spills;
- types and location of response equipment;
- target times for equipment deployment;

Environmental Effects Monitoring (EEM)

5.3.25 Characteristics of EEM programs for both routine and accidental events, including a description of the process by which these programs will be designed;

5.3.26 Parameters to be monitored and the rationale for their choice, including specific consideration of marine birds, reptiles and mammals; fisheries; fish and shellfish health/productivity and taint; fish habitat; and marine environmental quality;

5.3.27 Linkage of monitoring hypotheses to testable hypotheses (where available) identified by environmental assessment predictions;

5.3.28 Site-specific baseline information that is required to support monitoring programs;

5.3.29 Integration with other projects' programs (e.g., Hibernia, Terra Nova), including regional monitoring considerations;

5.3.30 Distinction of "signal" from "noise" in monitoring programs;

5.3.31 Independent/peer review of monitoring results;

5.3.32 Linkage of monitoring results into environmental management system;

5.3.33 Potential requirements for fish habitat compensation monitoring and for post-dredging monitoring

Abandonment/Decommissioning

5.3.34 Plans for abandonment and/or decommissioning of the project area and associated facilities following termination of production, including any anticipated requirement for post-abandonment monitoring.

APPENDIX 1

Departments and Agencies Consulted by C-NOPB

"Responsible Authorities" under the *Canadian Environmental Assessment Act*

Environment Canada

Fisheries and Oceans

Industry Canada

"Federal Authorities" under the *Canadian Environmental Assessment Act*

Atlantic Canada Opportunities Agency

Health Canada

Natural Resources Canada

Other Departments/Agencies

Canadian Environmental Assessment Agency

St. John's Port Authority

Provincial Departments (Government of Newfoundland and Labrador)

Department of Mines and Energy

Department of Environment and Labour

Department of Fisheries and Aquaculture

WHITE ROSE OILFIELD
COMPREHENSIVE STUDY

PART ONE
ENVIRONMENTAL IMPACT STATEMENT

SUBMITTED BY:

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1 INTRODUCTION

This Enviornmental Impact Statement (EIS) comprises Part One of the Comprehensive Study, which is prepared under the *Canadian Environmental Assessment Act* (CEAA).

Chapters 2 and 3 give a thorough overview of the physical and biological existing environment in the Grand Banks. Potential biophysical effects are assessed, including cumulative effects, in Chapter 4, which focuses on Valued Environemntal Components (VECs), identified as fish and fish habitat, marine birds, marine mammals and sea turtles. Discussion of the fishery is limited to those effects on fish and fish habitat that may affect commercial fisheries. Potential effects on the fisheries, with emphasis on commercial, economic and social aspects, are contained in the SEIS (Part Two).

Chapter 5 focuses on the likelihood of accidental events (e.g., oil spills) and makes effects predictions of an accidental event on each VEC. Chapter 6 details contingency planning. Chapter 7 discusses the follow up monitoring Husky Oil is recommending. Chapter 8 provides an overview of the Environmental Management System that will guide the development of the project, including the environmental protection plans. References are provided in Chapter 9.

2 REGIONAL SETTING (PHYSICAL ENVIRONMENT)

The White Rose oilfield is situated on the northeastern portion of the Grand Banks, in an open ocean site located approximately 350 km east of the Island of Newfoundland. The site is located in a water depth of approximately 120 m. As a result of its climatic, wave and current conditions, and its susceptibility to seasonal intrusions of sea ice and icebergs, the White Rose oilfield is situated in one of the harshest oceanic environments in the world.

The following sections provide a detailed overview of the existing physical environment at the White Rose site. This includes information regarding the area's weather and climate, wave conditions, bathymetry, water temperature and salinity, ocean currents, sea ice and icebergs, geology, shoreline environment, and water and sediment chemistry.

2.1 ATMOSPHERIC ENVIRONMENT

2.1.1 Overview of Marine Weather and Climate at White Rose

2.1.1.1 Setting

Since it is only approximately 53 km (30 nautical miles) from the Hibernia and Terra Nova fields, the White Rose oilfield is subject to the same synoptic weather systems; consequently, the marine climate at the site is quite similar.

Typical of middle latitude regions of the planet, the weather over the northwestern portion of the North Atlantic Ocean is characterized by frequent interchange of low and high pressure systems much of the year. These circulation systems are embedded in, and steered by, the prevailing westerly flow that typifies the upper levels of the atmosphere in the mid-latitudes, which arises because of the normal tropical to polar temperature gradient. The mean strength of the westerly flow is a function of the intensity of this gradient; as a consequence, it is considerably stronger in the winter months than during the summer months. The flow aloft is characterized by a varying wave pattern, which is interrupted at times by closed upper level cyclonic and anticyclonic circulation systems. Dynamical and thermodynamic processes associated with the varying wave pattern initiate the development and control the movement, evolution and ultimate intensity of the alternating low and high pressure features at the surface. Extra-tropical low pressure systems form and develop along frontal boundaries between air masses having different temperature and moisture characteristics. Frequently, there is an intensification of the air mass contrasts across the frontal boundaries during the initial stages of development.

With cooling of the atmosphere during fall and winter, there is an increase in the south to north temperature gradient, an attendant strengthening of the westerly winds aloft and an increase in the potential for storm development.

2.1.1.2 Winter Season Characteristics

The prevailing upper level pattern during the winter season causes low pressure systems to move through the Newfoundland region on a northeastward track, their course and intensity being dependent on the details of the upper level flow and the available potential energy. Typically, approximately two frontal low pressure systems move through the region each week; the intensity ranges from relatively weak features to major winter storm systems that affect a large area with storm-force winds and high seas.

In a case where the upper level long wave trough lies well west of the region, the main storm track will lie through the Gulf of St. Lawrence or Newfoundland. Under this regime, an east to southeast flow ahead of a warm front associated with the low will give way to winds from the south in the warm sector of the system. Typically, the periods of southerly winds and mild conditions will be of relatively long duration and, in general, the incidence of extended storm conditions is likely to be relatively infrequent. Strong frictional effects in the stable flow from the south results in a marked sheer in the surface boundary layer and relatively lower winds at the sea surface. As a consequence, local wind wave development tends to be inhibited under such conditions. Precipitation types are more likely to be in the form of rain or drizzle, with relatively infrequent periods of continuous snow, although periods of snow showers prevail in the unstable air in the wake of cold fronts associated with the lows. Visibility will be reduced at times in frontal and advection fogs, in snow and in snow shower activity.

At other times, with the upper long wave trough further to the east, the main storm track may lie through or to the east of the Grand Banks. With the lows passing closer to the site and frequent high potential for storm development, the incidence of strong gale and storm conditions is greater. Longer bouts of cold, west to northwest winds behind cold fronts occur more frequently, and because the flow is colder than the surface water temperatures, the surface layer is unstable. The sheer in the boundary layer is lower, resulting in relatively higher wind speeds near the surface and, consequently, relatively higher sea state conditions. With cold air and sea surface temperatures coupled with high winds, the potential for freezing spray will occur quite frequently. In this synoptic situation, a greater incidence of precipitation in the form of snow is likely to occur. Freezing precipitation, either as rain or drizzle, occurs rather infrequently on the Grand Banks. Visibility will be reduced in frontal and advection fogs and, relatively more frequently, by snow.

Frequently, intense low pressure systems become 'captured' and slow down or stall under an upper air low pressure centre as they move through the Newfoundland region or across the Labrador Sea. This may result in an extended period of little change in conditions that may range, depending on the position, overall intensity and size of the system, from the relatively benign to heavy weather conditions.

In some winters, stronger than normal northwesterly winds prevail over the northwestern North Atlantic. Such winters tend to be colder than normal, leading to greater ice growth along the Labrador Coast and to a more extensive incursion of sea ice over Newfoundland waters. The fetch available for wind wave development in west and northwest winds will be reduced as a consequence.

2.1.1.3 Summer Season Characteristics

With increasing solar radiation during the spring of the year, there is a general warming of the atmosphere that is relatively greater at higher latitudes. This decreases the north-south temperature contrast, lowers the kinetic energy of the westerly flow aloft and decreases the potential energy available for storm development. Concurrently, there is an northward shift of the main band of westerly winds at upper levels and a marked development of the Bermuda-Azores sub-tropical high pressure area to the south. This warm-core high pressure cell extends from the surface through the entire troposphere. The main track of the weaker low pressure systems typically lies through the Labrador region and tends to be oriented from the west-southwest to the east-northeast.

With low pressure systems normally passing to the north of the region in combination with the northwest shoulder of the sub-tropical high to the south, the prevailing flow across the Grand Banks is from the southwest during the summer season. Wind speed is lower during the summer and the incidence of gale or storm force winds relatively infrequent. There is a corresponding decrease in significant wave heights.

The prevailing southwesterly flow during the late spring and early summer tends to be moist and it is relatively warmer than the underlying surface waters on the Grand Banks. Cooling from below coupled with mixing of the air in the near-surface layer frequently results in saturation of the air, the condensation of water vapour and the development of advection fog, which may persist for days at a time. The incidence of advection fog and the frequency of poor visibility is normally highest during July.

On occasion, when an upper level high pressure circulation centre forms and persists over the southern portion of the United States as a westward extension of the sub-tropical high, an upper level trough tends to become established over the east coast region of Canada. While this upper pattern prevails, low pressure systems will tend to develop further south and track through the Newfoundland and Grand Banks regions.

2.1.1.4 Tropical Weather Systems

The hurricane season in the North Atlantic Basin extends from June through November. While the incidence of tropical depressions, storms, hurricanes or the remnants of such systems is infrequent, the risk of occurrence is greatest between August and October. The frequency of occurrence of tropical systems, or their remnants, affecting the region in any particular year is low and varies from none to a few. In accordance with the upper level circulation during the period, these systems normally approach the region from the south to southwest.

Tropical storms and hurricanes obtain their energy from latent heat of vapourization that is released during the condensation process. Since the capacity of the air to hold water vapour is dependent on temperature, the trajectory of the systems over the cooler waters of the northwest Atlantic normally reduces the available water vapour supply and leads to a weakening of the systems. The rate of weakening, however, may be slow. As tropical systems weaken, they frequently evolve into conventional but rather substantial extra-tropical storm systems. Conditions on the Grand Banks associated with tropical cyclones and their remnants vary widely from relatively minor events to major storms.

2.1.2 Availability of Marine Climate Data

Marine weather observations recorded on board vessels and drilling platforms on the Grand Banks are the primary data source upon which the climate statistics for White Rose have been developed. Shipboard observations are taken on a volunteer basis under a program of international cooperation that began in the mid-nineteenth century. When taken, these observations are typically made at the main synoptic observation times of 0000, 0600, 1200, and 1800 UTC, following World Meteorological Organization (WMO) practices and procedures. For Canadian Selected Ships, these guidelines are described in Environment Canada (1996). In addition to near real-time use by public and private forecast services, these data are archived in the Comprehensive Ocean-Atmosphere Data Set (COADS) on a worldwide basis by the U.S. National Oceanic and Atmospheric Administration.

While the ship-based reports have been quality controlled to the extent possible, they are likely to contain some observation errors, in addition to position report errors, particularly for the older reports. As well, the data set is known to contain a 'fair weather bias', which arises because: ship's captains may choose to avoid areas of heavy weather, and since the reporting program is voluntary, fewer observations are likely to be taken under adverse weather and sea state conditions. This bias is more likely to be present during the winter season and over temperate and northern seas where vessel traffic is light.

Since the 1970s, the COADS database for the Grand Banks has been augmented with routine marine weather observations taken by observers on board exploration and production platforms, in accordance with guidelines established by the National Energy Board (NEB) (1994) and the C-NOPB. Frequently referred to as MANMAR reports, these observations are also taken in accordance with the practices and procedures described in Environment Canada (1996). Because the observations are routinely taken at three intervals at the main and intermediate synoptic hours during all drilling programs, the rig-based observations do not contain fair weather bias. Reported wind speeds, however, are typically higher than nearby ship-based wind speed observations. This bias occurs because the wind speed normally increases with height in the marine surface boundary layer and because anemometers on drilling platforms are normally located at the crown of the derrick at an elevation of approximately 80 m above the sea surface, well above a typical shipboard anemometer installation. Adjustment of the ship- and rig-based wind speed observations to a standard reference height in the surface boundary layer can be made if the air-sea temperature difference and the instrumentation heights are available (Smith 1981; 1988).

Rig, vessel and marine synoptic observations may include the following parameters:

- platform identifier;
- date and time;
- position, direction and speed of travel;
- wind direction and speed;
- air temperature, wet bulb temperature, dew point temperature and sea surface temperature;
- sea level pressure, three-hour characteristic and amount of pressure tendency;
- total sky cover, type of low, middle and high cloud and height and amount of base cloud layer;
- visibility;
- present and past weather (precipitation type, obstructions to vision, and so forth);
- period and height of the local wind waves (sea); and
- direction, period and height of the primary and secondary swell.

While drilling operations are being conducted, a Datawell Waverider non-directional wave buoy is normally deployed approximately 1 km (0.5 nautical miles) from the platform. Wave buoys provide real-time measured wave data, which are incorporated into the marine weather reports. Normally, the critical wave height and peak spectral period derived from the buoy data are archived for use in determining wave climate statistics for the area.

Hindcast wave data provide a valuable source of wave information that may be used when measured wave data are not available, or when the period of record is short or discontinuous. In addition to providing a time-series of conventional wave statistics over an extended period, hindcast model output also provides directional spectra at each grid point and time. The spectra can be manipulated to provide wave direction parameters that may not be available from other sources.

Wave hindcasts are conducted by providing a time-series of arrays of analyzed surface winds to a numerical wave model. In broad terms, the output is dependent on the accuracy of the input wind data, the resolution model grid and on the skill of the model.

2.1.2.1 Data Sources Used

The following data sets were used to derive the marine climate statistics for White Rose:

1. COADS ship and rig marine synoptic observations for the area from 46°00'N to 48°00'N, between 047°00'W and 048°00'W, from the years 1950 through 1995, provided from a sub-set of COADS records by Meteorological Service of Canada, Environment Canada.

2. Marine weather observations from Husky/Bow Valley East Coast Project and Husky Oil Operations Ltd. (Husky Oil) exploratory drilling operations on the Grand Banks during the 1980s and 1990s. A list of the well sites is given in Appendix 2.A.

   These data were extracted from the Canadian Offshore Oil and Gas Environmental Data CD-ROM (March 1997) compiled by Marine Environmental Data Service (MEDS), Ottawa.

3. Hibernia nine-yr continuous environmental data time-series for the period January 1, 1980 through December 31, 1988. This data set was prepared under contract to the Hibernia Management and Development Company Ltd. (HMDC) by Seaborne Limited. The time-series is a composite of three-hourly marine weather observations (wind speed and direction) and Waverider buoy data (significant wave height and peak period) from a number of drilling programs on the Grand Banks. It also contains current direction and speed data. The wind speed data are from anemometers located approximately 80 m above the sea surface.

   This data set provides a reasonable estimate of the wind and wave climate in the area and, moreover, is sufficient to enable persistence studies to be carried out and to gain an appreciation of the interannual variability that can be expected.

4. Analyzed surface winds and hindcast wave data extracted from 40-yr hindcast database (AES40) recently completed by Oceanweather Limited of Cos Cob, Greenwich, Connecticut under contract to Environment Canada. Observed winds were adjusted to a standard reference level of 10 m above the sea surface, then objectively analyzed on a 0.625° latitude by 0.875° longitude grid over the North Atlantic Ocean. The time step used was six hours for the entire period from 1958 through 1997.

For this study, the interpolated 10-m wind speeds and directions, and hindcast significant wave height data extracted from the AES40 database for grid point 5622 at 46.875°N 048.3333°W were used.

2.1.3 Wind

2.1.3.1 Definitions

According to the MANMAR manual (Environment Canada 1996), wind is the effect produced by the horizontal motion of air across the surface of the Earth or at any altitude above the surface. The motion of air is caused by differences in the atmospheric pressure between two localities. Air tends to move from an area of relatively high pressure to one of relatively low pressure, and may be likened to the flow of water downhill. However, the air does not flow directly from high to low pressure, but moves at a small angle to the direction of the lines of equal pressure, called isobars on a weather map. The speed of the wind is directly proportional to the rate at which the atmospheric pressure is changing across the Earth's surface. If the pressure changes rapidly in a horizontal direction, the wind is strong; if it changes slowly, the wind is light.

In a MANMAR coded observation, the mean direction and speed of the wind over a 10-minute period immediately preceding the observation time is reported. The mean wind direction is reported in degrees True, rounded to the nearest 10°. The direction is the direction from which the wind is blowing. In a MANMAR coded observation, the wind speed may be in knots or metres per second. In this section of the report all wind speeds are given in knots. In a MANMAR coded observation, there is no provision for reporting wind speeds in gusts and squalls.

2.1.3.2 Wind Speeds

Figures presented in Appendix 2.B show the percentage wind speed exceedance curves for each month of the year.

The AES40 wind values are for 10 m above sea level. The Husky Oil and Hibernia values are for winds reported at the anemometer height. The anemometer height of different drilling rigs varies, but in general, is approximately 80 m above sea level. The COADS values contain ship reports and drilling rig reports. The mean height of these reports will be somewhere between 10 and 80 m above sea level.

2.1.3.3 Maximum Wind Speeds

The maximum wind reported from each direction for the Husky Oil and Hibernia data sets are shown in Tables 2.1-1 and 2.1-2. These are anemometer height winds. The monthly max-min columns show the highest and lowest maximum wind reported for each month.

Table 2.1–1 Husky Oil Highest Monthly Anemometer Wind Speed (Knots) From Each Direction

Month	Direction								Monthly	
	NE	E	SE	S	SW	W	NW	N	Min	Max
January	46	48	62	64	65	65	59	48	46	65
February	58	60	60	56	71	55	50	45	45	71
March	39	50	58	57	56	55	50	50	39	58
April	52	60	50	55	51	45	44	45	44	60
May	40	42	38	56	50	50	55	52	38	56
June	39	36	47	55	50	40	37	42	36	55
July	33	35	45	52	52	43	40	38	33	52
August	42	39	42	52	45	46	37	75	37	75
September	52	53	65	57	63	50	72	50	50	72
October	44	33	43	52	45	49	53	91	33	91
November	46	40	40	56	48	64	62	53	40	64
December	37	45	57	67	72	65	55	50	37	72
Years Max	58	60	65	67	72	65	72	91		

Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99)

Table 2.1–2 Hibernia Highest Monthly Anemometer Wind Speed (Knots) From Each Direction

Month	Direction								Monthly	
	NE	E	SE	S	SW	W	NW	N	Min	Max
January	75	63	58	64	72	65	52	71	52	75
February	68	61	70	78	76	81	60	74	60	81
March	59	61	55	63	59	60	70	68	55	70
April	60	48	50	68	58	51	54	53	48	68
May	39	41	46	50	47	40	45	55	39	55
June	40	50	53	47	55	44	34	32	32	55
July	40	30	42	50	48	50	50	39	30	50
August	52	46	42	45	45	44	76	58	42	76
September	51	50	58	58	99	60	69	48	48	99
October	49	55	50	55	48	56	52	49	48	56
November	48	50	56	64	77	75	78	51	48	78
December	54	47	77	63	59	77	62	66	47	77
Years Max	75	63	77	78	99	81	78	74		
Data source: Hibernia nine-yr time-series 1980 to 1988										

The Husky Oil data set has a maximum wind of 91 kts (47 m/s) from the north in October. The Hibernia data set records a maximum wind of 99 kts (51 m/s) from the southwest in September. These maximum winds were most probably associated with a hurricane or tropical storm passing very close to the observation location.

2.1.4 Winds by Direction

The percentage of wind reports blowing from each direction for each month from the AES40 data set is shown in Table 2.1-3.

Table 2.1–3 Monthly Percentage Frequency of Wind Direction

Month	Direction								Total Reports
	NE	E	SE	S	SW	W	NW	N	
January	4.6	4.3	7.1	11.9	18.3	**29.2**	17.5	7.1	4,959
February	5.5	5.4	8.0	11.7	15.7	**27.4**	18.3	7.9	4,520
March	7.9	6.6	7.4	12.5	17.6	**22.5**	15.4	10.2	4,960
April	7.8	8.4	10.5	13.0	**19.2**	17.5	13.7	9.9	4,801
May	8.1	6.5	8.7	16.4	**22.3**	16.4	12.1	9.6	4,960
June	4.8	4.3	7.2	17.9	**34.1**	16.1	8.4	7.3	4,800
July	2.7	3.0	6.4	21.4	**39.8**	16.6	6.5	3.6	4,960
August	4.7	3.8	7.7	18.2	**32.3**	18.5	8.5	6.4	4,960
September	6.3	4.8	6.1	15.1	**22.6**	21.5	14.8	8.8	4,800
October	4.5	4.4	6.8	14.2	19.7	**22.8**	18.3	9.3	4,960
November	4.8	5.0	8.2	13.6	17.7	**21.5**	19.0	7.0	4,800
December	4.6	4.4	7.9	13.4	16.1	**26.6**	17.8	9.1	4,960
Years Mean	5.5	5.1	7.7	15.0	23.0	21.4	14.2	8.0	

Notes: Highest monthly percentage is bolded
Data source: AES grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1997

The highest monthly percentage is highlighted in bold. This represents the prevailing wind direction for each month. It clearly shows a prevailing westerly wind for six months of the year centred on the winter months and a prevailing southwesterly wind centred on the summer months for the other six months.

2.1.5 Gales and Storms

The winds at the 10-m level (data taken from the AES40 dataset) exceeding 33 kts (17 m/s) are shown in Table 2.1-4. This includes any gale-force winds, storm-force winds and hurricane-force winds. In January, 376 of a total of 4,959 six-hourly sample winds were greater than 33 kts (17 m/s). This is equivalent to 7.6 percent. Of the 376 samples greater than 33 kts (17 m/s), 36.2 percent of them blew from the west.

Table 2.1–4 10-m Level Winds Exceeding 33 Knots (Percentage)

Month	Wind Direction								Sample Winds > 33 Kts	Total Wind Samples	Percent Winds > 33 Kts
	NE	E	SE	S	SW	W	NW	N			
January	1.3	1.6	4.5	14.4	21.3	**36.2**	16.5	4.3	376	4,959	7.6
February	4.1	1.3	5.3	13.5	15.4	**30.8**	23.3	6.3	318	4,520	7.0
March	9.1	4.3	7.5	16.1	17.7	**26.3**	10.8	8.1	186	4,960	3.8
April	5.2	3.9	7.8	16.9	10.4	**22.1**	16.9	16.9	77	4,801	1.6
May	0.0	0.0	13.0	4.3	**26.1**	4.3	39.1	13.0	23	4,960	0.5
June	0.0	16.7	8.3	8.3	**25.0**	**25.0**	16.7	0.0	12	4,800	0.3
July	0.0	0.0	0.0	**66.7**	33.3	0.0	0.0	0.0	3	4,960	0.1
August	10.0	0.0	10.0	20.0	20.0	10.0	0.0	**30.0**	10	4,960	0.2
September	11.1	8.9	0.0	24.4	6.7	**26.7**	20.0	2.2	45	4,800	0.9
October	10.2	3.4	2.3	14.8	10.2	17.0	**25.0**	17.0	88	4,960	1.8
November	3.9	3.4	5.1	14.0	10.7	24.7	**28.7**	9.6	178	4,800	3.7
December	1.4	1.7	9.2	16.1	14.4	**32.5**	13.7	11.0	292	4,960	5.9

Notes: Highest monthly percentage is bolded
Data source: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

The winds at the 80 m level (data taken from the Husky Oil dataset) exceeding 33 kts (17 m/s) are shown in Table 2.1-5. In January 33.4 percent of the reported winds exceeded 33 kts. This is considerably higher than the 7.6 percent of winds at the 10 m level exceeding 33 kts for the same month.

The much higher occurrence of winds greater than 33 kts (17 m/s) at the 80 m level than at the 10 m level is illustrated in Figure 2.1-1. This may lead one to suspect that the 10 m winds from the AES40 hindcast are too low. However, when these winds are put into the wave model, they produce wave heights as high as or higher than the waves reported by the Husky Oil observers. If the hindcast winds were too low, then the waves they would generate would also be too low, but this is not the case.

Therefore, when one is dealing with winds offshore, it is very important to know the height at which these winds were observed above the sea surface.

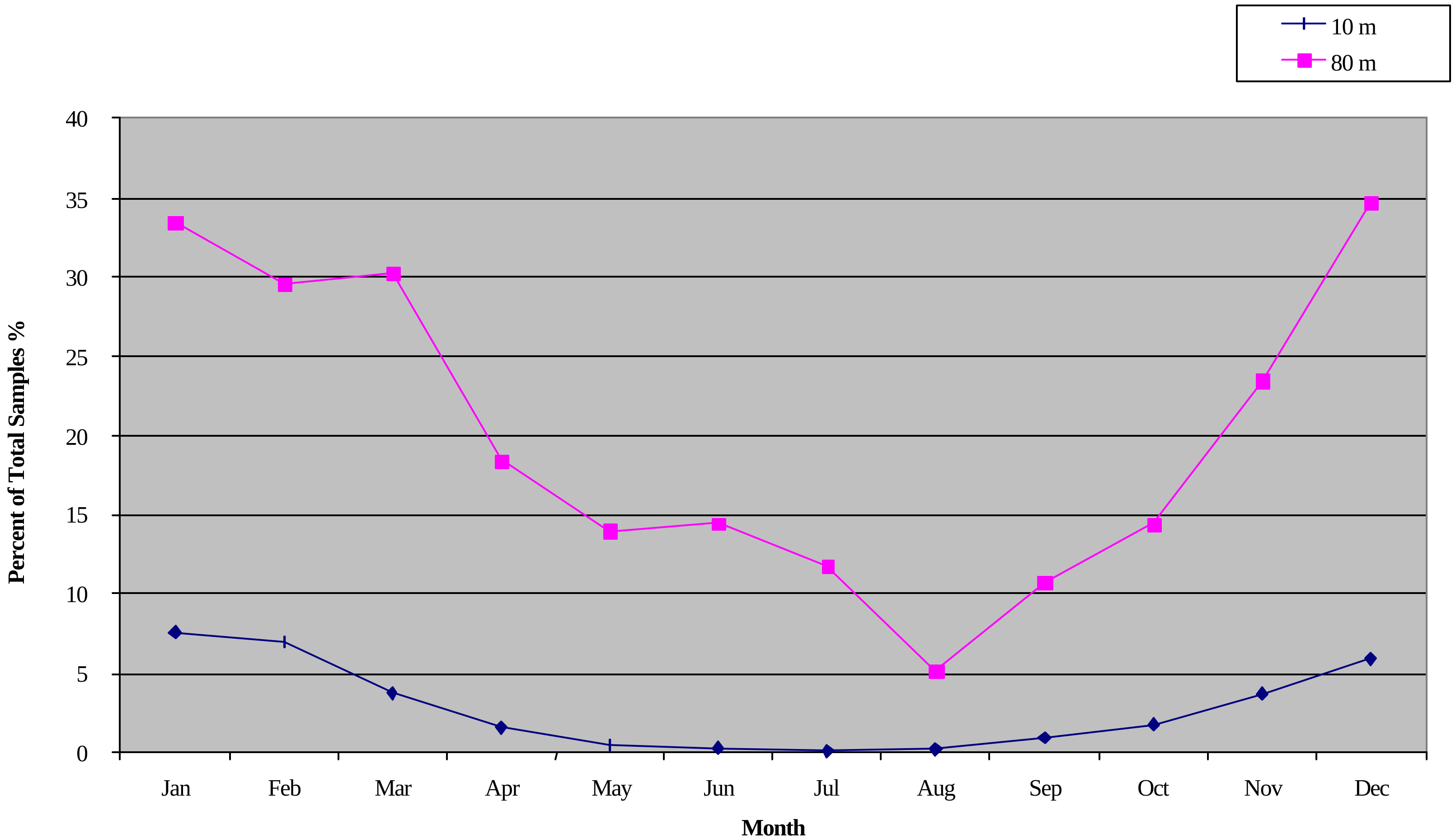
Table 2.1–5 80 m Level Winds Exceeding 33 Knots (Percentage)

Month	Wind Direction								Sample Winds > 33 Kts	Total Wind Samples	Percent winds > 33 Kts
	NE	E	SE	S	SW	W	NW	N			
January	1.5	1.2	8.3	22.4	23.6	**32.1**	6.6	4.2	589	1,763	33.4
February	1.5	2.7	13.9	13.5	16.6	**38.6**	8.1	5.0	259	877	29.5
March	1.0	4.8	5.4	25.8	21.0	**26.1**	13.7	2.2	314	1,039	30.2
April	3.9	19.9	13.1	**31.1**	9.2	4.4	3.9	14.6	206	1,120	18.4
May	2.0	5.4	2.0	**57.6**	15.6	4.9	8.8	3.9	205	1,469	14.0
June	1.9	1.4	9.0	**60.2**	22.3	2.4	0.5	2.4	211	1,459	14.5
July	0.0	0.4	4.3	42.4	**42.9**	4.8	3.5	1.7	231	1,968	11.7
August	4.3	3.2	4.3	**30.9**	26.6	9.6	10.6	10.6	94	1,815	5.2
September	8.9	4.4	3.3	18.9	**22.8**	15.0	19.4	7.2	180	1,678	10.7
October	2.2	0.0	3.1	**30.6**	17.9	8.7	21.8	15.7	229	1,588	14.4
November	4.8	6.0	2.4	12.3	15.3	**25.5**	**25.5**	8.1	333	1,422	23.4
December	0.2	1.4	2.7	18.1	19.4	**43.9**	11.7	2.7	515	1,484	34.7

Notes: Highest monthly percentage is bolded
Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99)

A general trend is for strong wind events to blow from the south or southwest in the summer, from the west or northwest in the fall and from the west over the winter.

Figure 2.1–1 Comparison of Winds Greater Than 33 Knots at the 10 m Level and 80 m Level



Source: 80 m winds; Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).
10 m winds; AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998.

2.1.6 St. John's Winds

St. John's winds have been included in Table 2.1-6 for comparison purposes.

Table 2.1–6 St. John's Monthly Wind Statistics

Month	Prevailing Wind Direction	Mean Speed (kts)	Maximum Speed (kts)	Maximum Gust (kts)
January	W	15	65	90
February	W	15	74	104
March	W	14	65	104
April	W	13	50	86
May	W	12	55	79
June	SW	12	40	58
July	SW	11	36	58
August	SW	11	45	61
September	W	11	52	83
October	W	12	56	83
November	W	13	57	87
December	W	15	52	83
Data source: Canadian Climate Normals 1942 to 1990 (AES 1991)				

2.1.7 Weather Variabilities

The following definitions are used to describe weather variabilities.

- Visibility - According to the MANMAR manual (Environment Canada 1996), visibility is defined as the greatest distance at which a dark object of suitably large dimensions can be seen and identified when observed against a background of sky or fog. In the case of night observations, it is the distance at which it could be seen and identified if the general illumination were raised to the normal daylight level.

- Fog - According to the MANMAR manual (Environment Canada 1996), fog is a suspension of very small water droplets in the air, reducing the visibility at the Earth's surface. The term "fog" is restricted to cases in which the horizontal visibility at the Earth's surface is less than 1 km (0.5 nautical miles). Rime is caused by the solidification into ice of super-cooled water droplets in a fog coming into contact with solid objects at a temperature below the freezing point. With persistent fog and below freezing temperatures, rime may grow to a considerable thickness, 2.5 cm or more. The growth is in the direction from which the water droplets are being carried by the wind. The deposit is white and feathery.

- Precipitation - According to the MANMAR manual (Environment Canada 1996), precipitation is any product of the condensation of atmospheric water vapour that is deposited on the Earth's surface. The most common types of precipitation are liquid (rain and drizzle) and solid (snow, hail, ice pellets, snow pellets and snow grains). Freezing rain is rain, the drops of which freeze on impact with the ground or with objects on the Earth's surface. Freezing drizzle is drizzle, the drops of which freeze on impact with the ground or with objects on the Earth's surface.

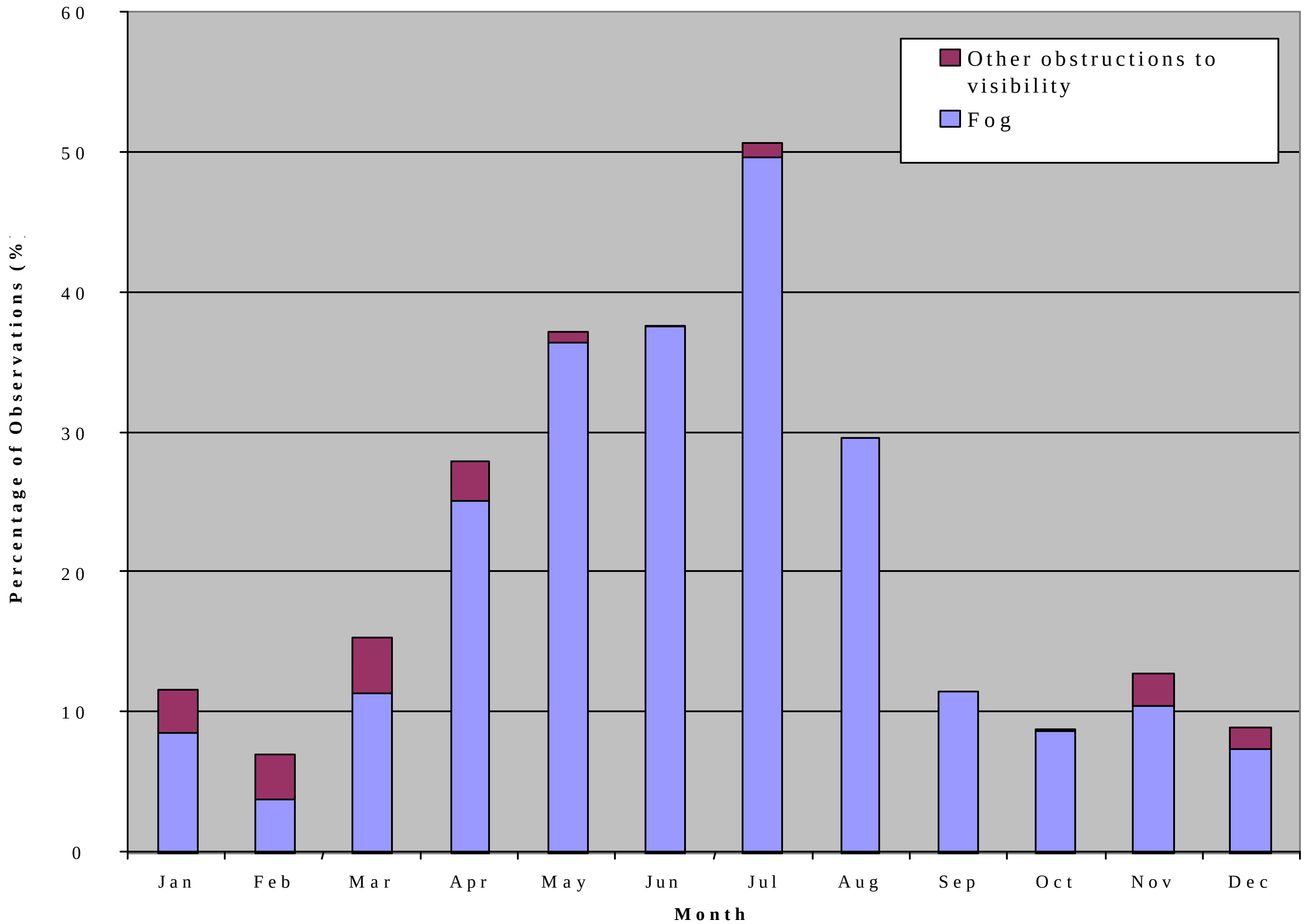
- Thunderstorm - According to the MANMAR manual (Environment Canada 1996), a thunderstorm is considered to be occurring at the vessel when thunder is heard or overhead lightning is observed and the local noise level is such as might prevent hearing thunder. Hail may also be an indicator of a thunderstorm in progress.

2.1.8 Visibility

If the atmosphere were perfectly transparent, it would be possible, within the limits imposed by the Earth's curvature, to identify objects at exceedingly great distances. This ideal situation rarely occurs in nature, however, as there are always some tiny particles of solid or liquid matter suspended in the atmosphere. Light rays coming from an object at a given distance from the observer are scattered by these suspended particles, the amount of scattering depending on the concentration of the particles. In a dense concentration, as in a thick fog, light may be totally scattered in a distance as small as 50 m, rendering objects at this distance invisible. Some conditions that may reduce the visibility in the atmosphere are fog, mist, haze, smoke, snow, drizzle, rain and blowing spray.

The percentage of observations by month that reported a visibility of less than 1 km (0.5 nautical miles) are shown in Figure 2.1-2. The main cause of the reduced visibility was due to fog. Other obstructions to visibility reported were generally drizzle, rain and snow. A combination of any number of these obstructions to visibility may have occurred at the same time.

Figure 2.1–2 Percentage Occurrence of Visibility Less than 0.5 Nautical Miles (Due to Fog or Other Obstructions to Visibility)



Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).

The percentage occurrence of visibilities in various ranges are shown in Figure 2.1-3. These ranges have been chosen to coincide with the ranges used in the MANMAR reporting code.

One of the main effects of poor visibility at White Rose will be on helicopter movements. Helicopter operations are generally severely restricted in visibilities of less than 1 km (0.5 nautical miles).

2.1.9 Precipitation

The percentage occurrence of precipitation types are shown in Figure 2.1-4.

The number of observations reporting freezing precipitation out of an average of 10,000 observations each month are shown in Figure 2.1-5. Precipitation amounts are not normally measured in marine observations.

One of the main effects of precipitation at White Rose will be on helicopter movements. Precipitation may reduce the visibility to less than 1 km (0.5 nautical miles). Reported or forecast freezing precipitation may also severely restrict helicopter operations due to the risk of aircraft icing.

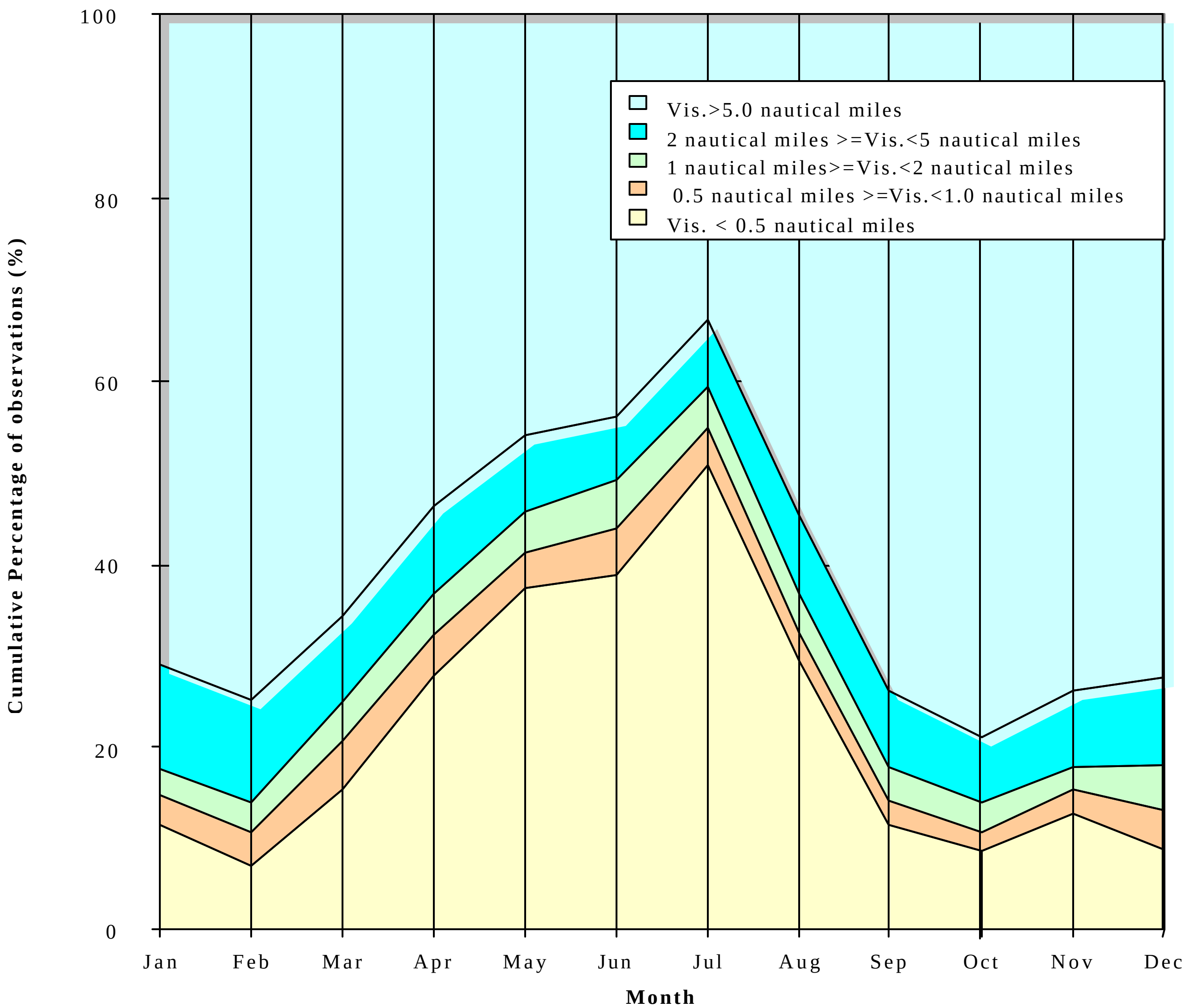
Freezing precipitation is a comparatively rare event on the Grand Banks, but it may cause some ice accretion on marine vessels.

2.1.10 Thunderstorms

The number of thunderstorms reported in each month (taken from the COADS data for the area enclosed by 46°00´ to 48°00´ N and 47°00´ to 49°00´ W) from 1950 to 1995 is shown in Figure 2.1-6. The total number of observations reporting weather in this data set is 123,518.

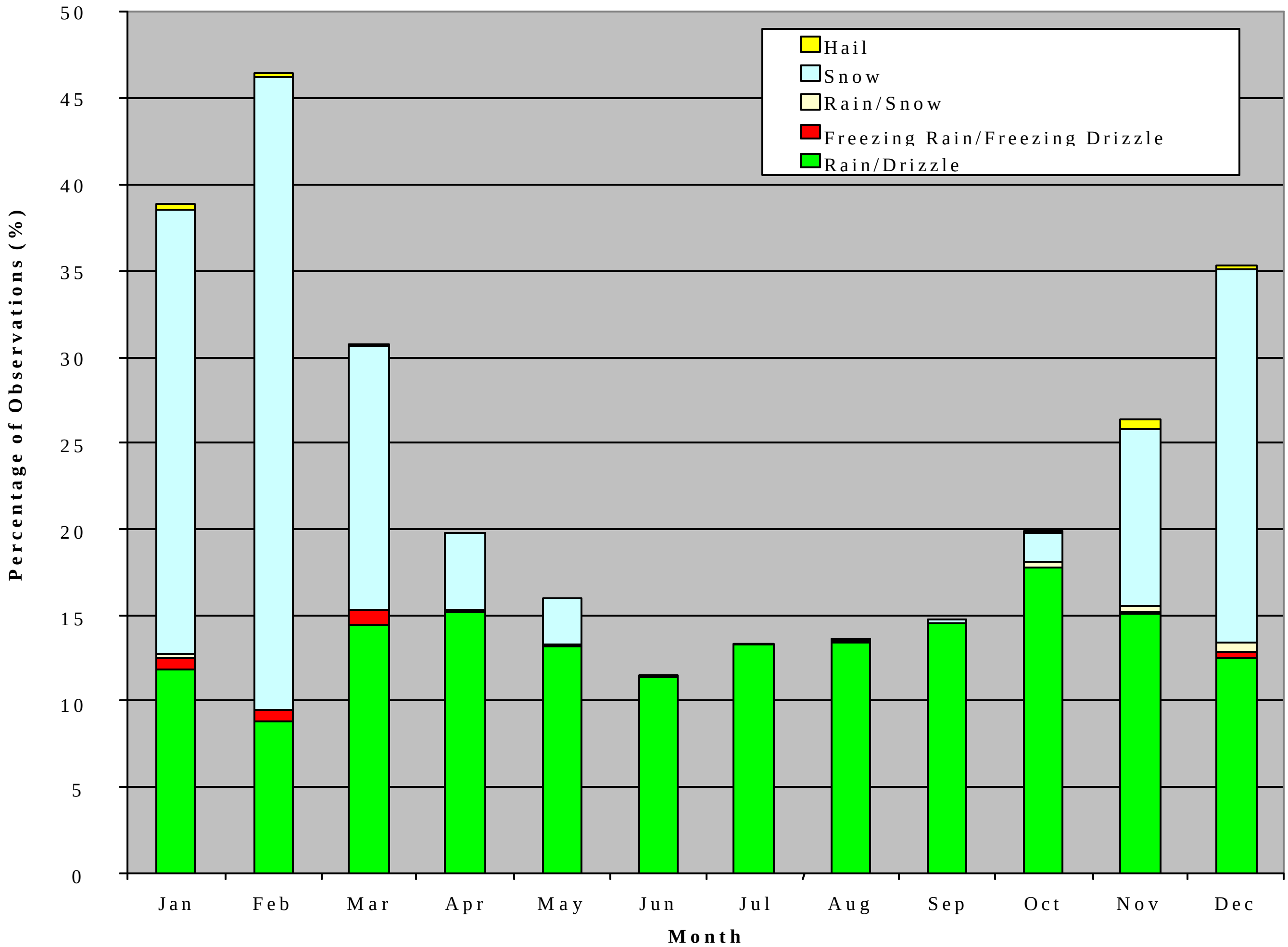
Although thunderstorms are rare on the Grand Banks, when they do occur or are forecast, they can have an affect on operations. Helicopters may be affected by strong squally winds (both vertical and horizontal) giving severe or extreme turbulence. There is a risk of icing in thunderclouds (cumulonimbus). Strong squally winds and the risk of lightning may also affect marine operations.

Figure 2.1–3 Cumulative Percentage Occurrence of Visibility



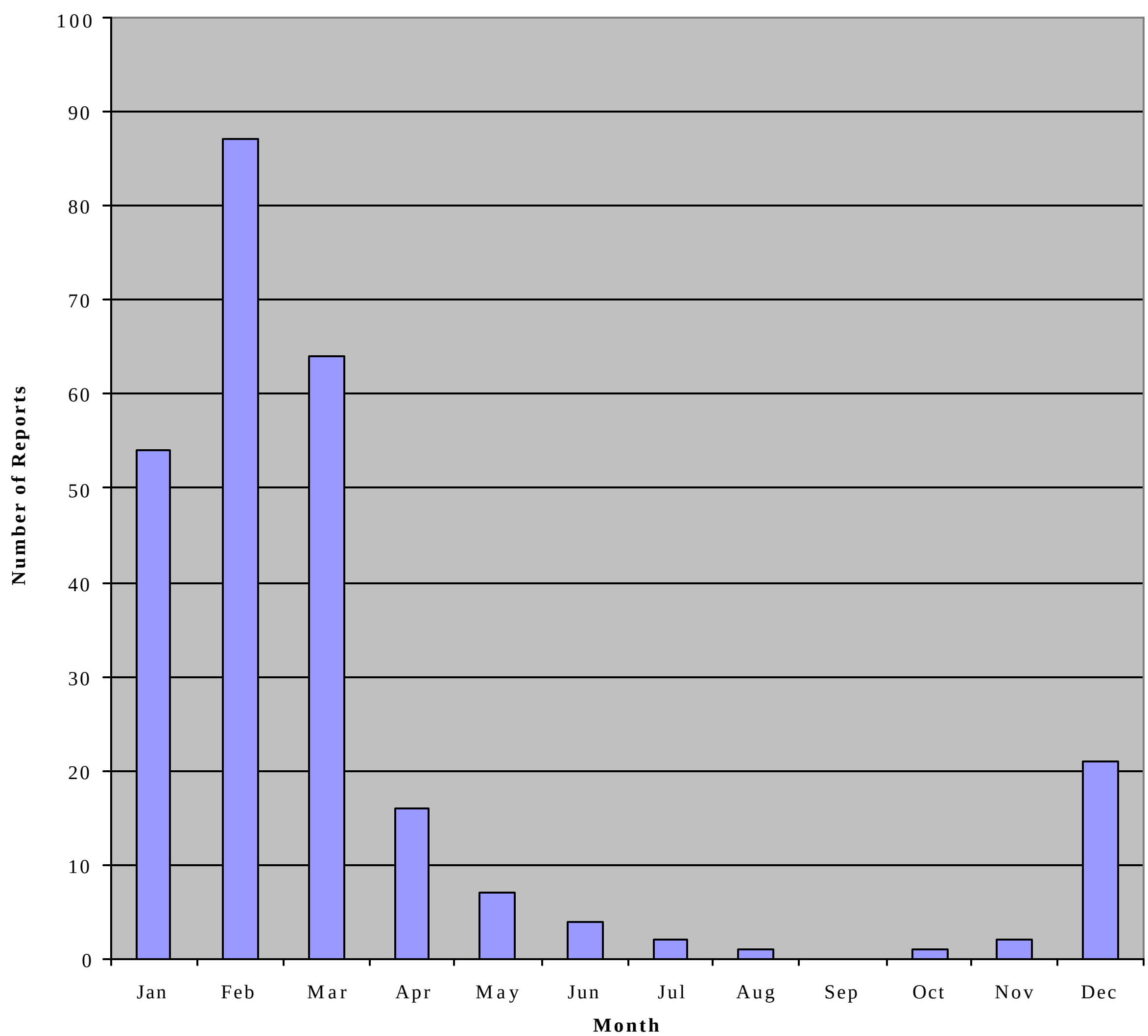
Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).

Figure 2.1–4 Percentage Occurrence of Precipitation Types



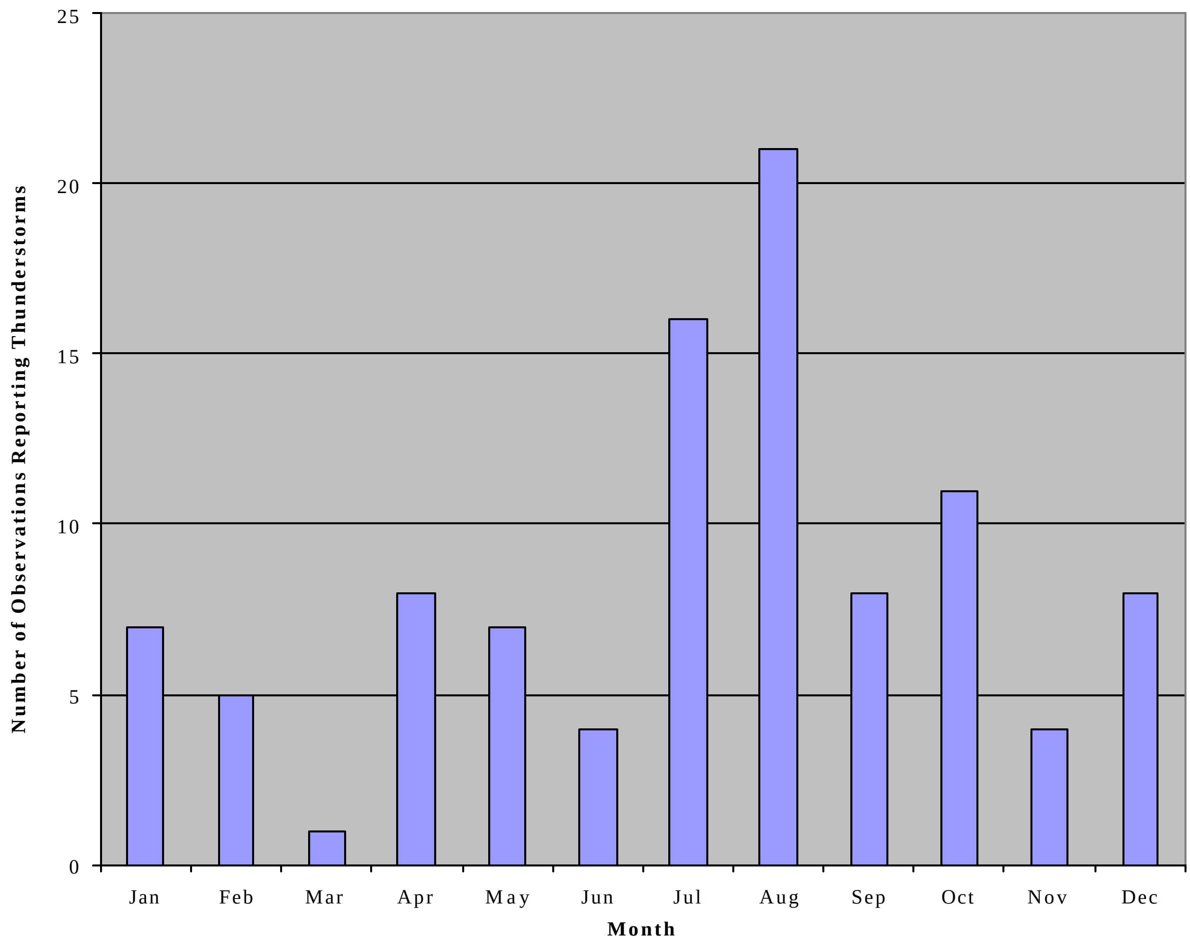
Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).

Figure 2.1–5 Freezing Precipitation



Source: COADS data for block 46-48N 47-49W, 1950 to 1995.

Figure 2.1–6 Number of Reports of Thunderstorms



Source: COADS data for block 46-48N 47-49W, 1950 to 1995.

2.1.11 St. John's Weather

General weather statistics for St. John's Airport (taken from the Environment Canada Canadian Climate Normals) are shown in Table 2.1-7.

Table 2.1–7 St. John's General Weather Statistics

Month	Days with				
	Measurable Rainfall	Measurable Snowfall	Freezing Precipitation	Thunderstorms	Fog
January	9	18	7	*	7
February	8	16	7	*	7
March	11	14	9	*	10
April	12	9	8	*	14
May	15	3	1	*	16
June	15	*	0	*	14
July	14	0	0	1	13
August	15	0	0	1	10
September	16	*	0	*	8
October	19	2	0	*	7
November	16	8	1	*	8
December	12	16	4	*	7
Notes: * represents less than one day but greater than zero Data source: Canadian Climate Normals 1942 to 1990 (AES 1991)					

2.1.12 Temperature

The following definitions are used to describe temperature.

- Sea Surface Temperature - According to the MANMAR manual (Environment Canada 1996), the sea surface temperature is the temperature of the water in the surface layer of the sea, expressed in degrees Celsius. The preferred method of measuring the sea surface temperature is by means of a special sea temperature bucket lowered into the water over the side of the vessel. If this method is not practical, the sea surface temperature may be obtained from the thermometer located in the engine room intake pipe of the vessel.

- Air Temperature - According to the MANMAR manual (Environment Canada 1996), the dry bulb temperature, expressed in degrees Celsius, is a measure of the amount of heat in the air. This is the temperature that is indicated by a standard thermometer when properly ventilated and shielded from the direct rays of the sun.

Monthly sea surface temperature statistics are provided in Table 2.1-8. A plot of the monthly minimum, mean and maximum values is shown in Figure 2.1-7.

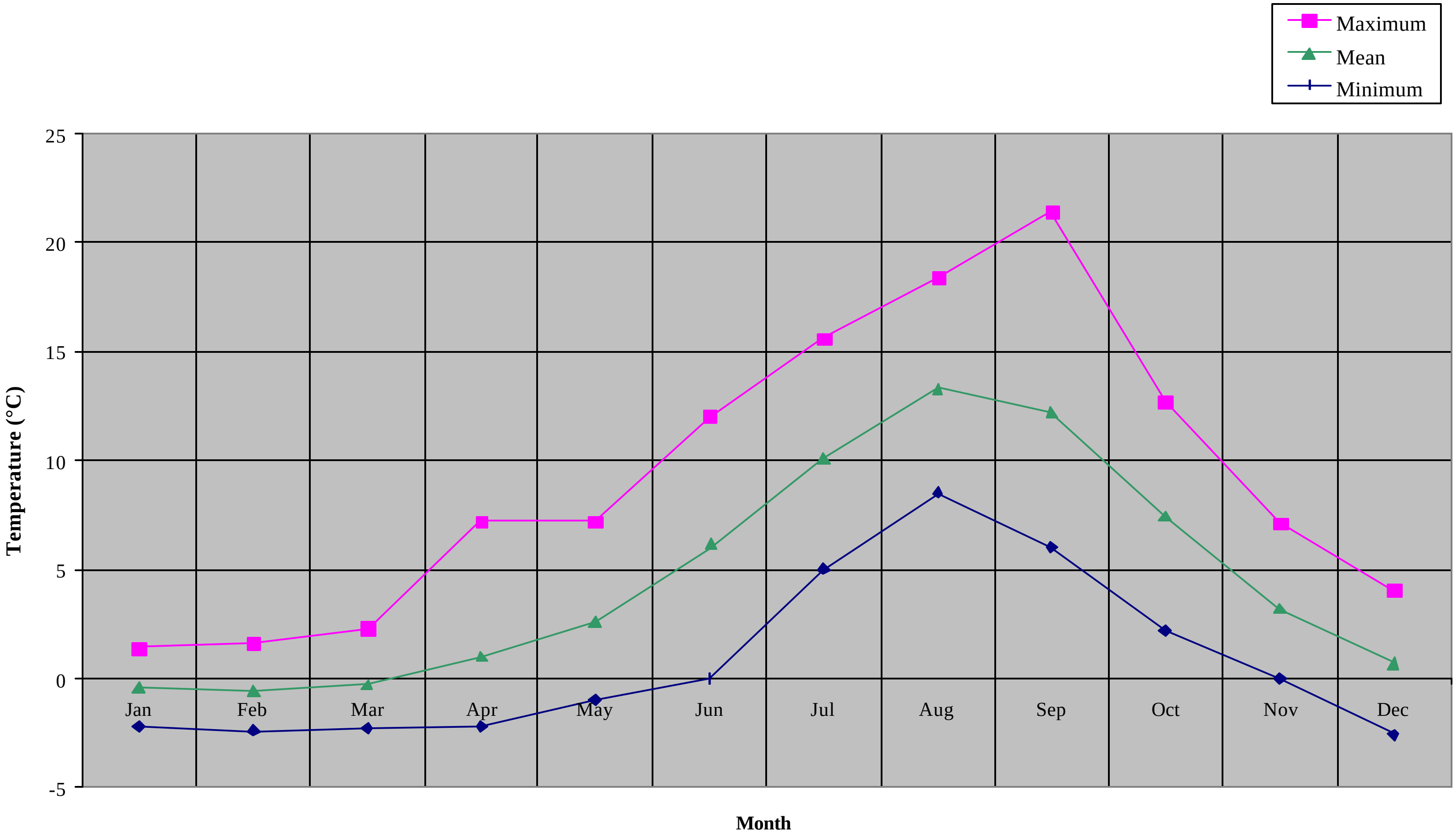
Table 2.1–8 Monthly Sea Surface Temperature Statistics

Month	Temperature (°C)			Standard Deviation
	Minimum	Maximum	Mean	
January	-2.2*	1.4	-0.4	0.7
February	-2.4*	1.6	-0.6	0.7
March	-2.3*	2.3	-0.3	0.9
April	-2.2*	7.2	1.0	1.3
May	-1.0	7.2	2.6	1.8
June	0.0	12.0	5.9	1.7
July	5.0	15.6	10.1	1.9
August	8.5	18.4	13.3	2.2
September	6.0	17.4	12.2	1.9
October	2.2	12.7	7.4	2.2
November	0.0	7.1	3.2	1.3
December	-2.6*	4.0	0.7	1.0

*Note: The minimum values for sea surface temperature in the data set are erroneously too low during winter presumably due to the method of measurement. Since the temperature was taken with a non-reversing thermometer, it was probably affected by the air temperature during reading. The sea surface temperature at White Rose should not go below –1.8ºC.

Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99)

Figure 2.1–7 Monthly Sea Surface Temperature



Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).

Husky Oil White Rose Environmental Data (Jun 99 to Oct 99)

Monthly air temperature statistics are provided in Table 2.1-9. A plot of the monthly minimum, mean and maximum values is shown in Figure 2.1-8.

Table 2.1–9 Monthly Air Temperature Statistics

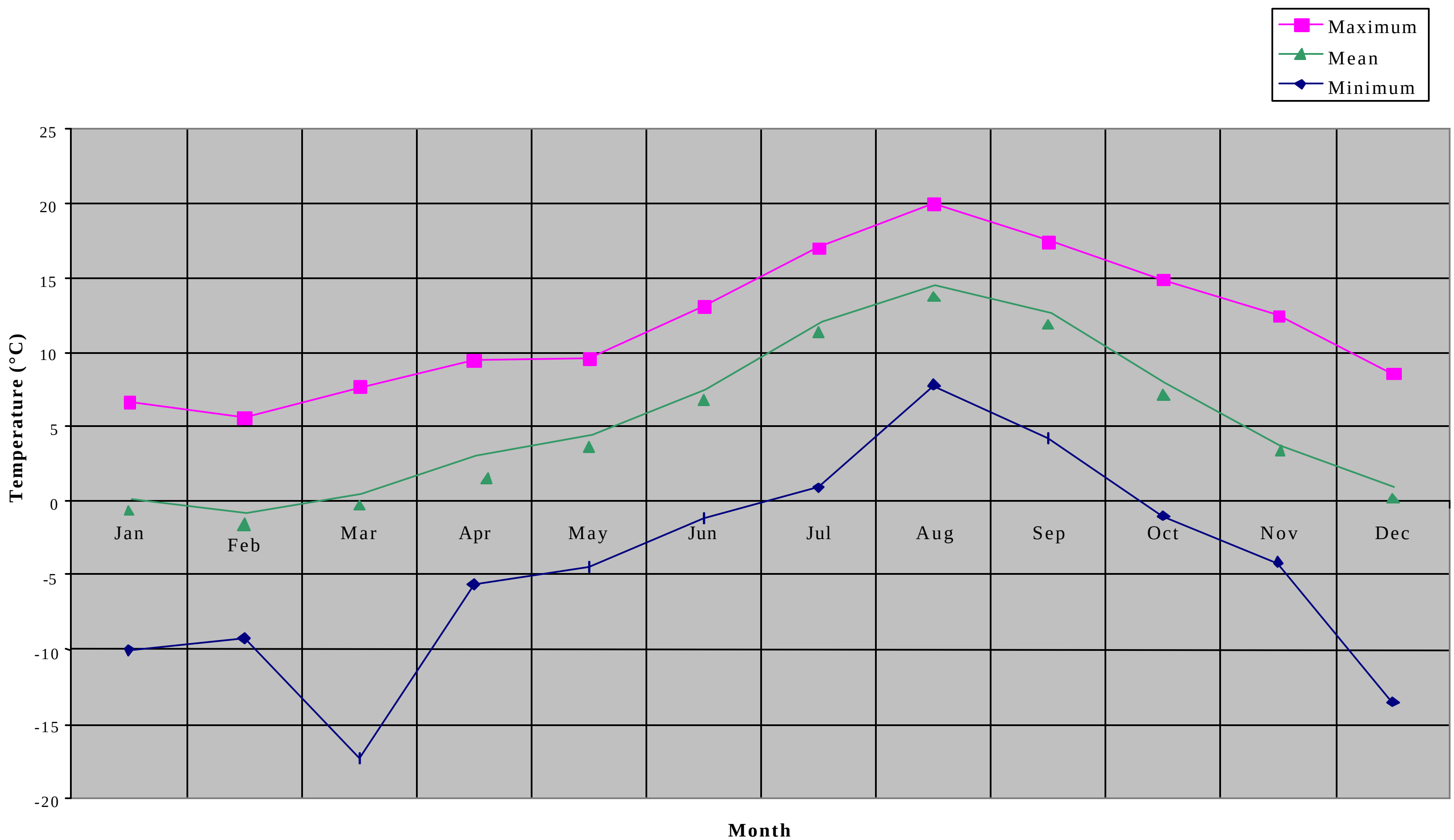
Month	Temperature (°C)			Standard Deviation
	Minimum	Maximum	Mean	
January	-10.0	6.7	-0.6	2.8
February	-9.2	5.6	-1.6	2.7
March	-17.3	7.7	-0.3	3.5
April	-5.6	9.5	2.3	2.1
May	-4.4	9.6	3.7	2.4
June	-1.2	13.1	6.8	2.4
July	0.9	17.0	11.3	2.1
August	7.8	20.0	13.7	2.3
September	4.2	17.5	11.9	2.4
October	-1.0	14.9	7.2	2.9
November	-4.1	12.5	3.0	2.4
December	-13.5	8.6	0.2	3.0

Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99)

Air/Sea Temperature Relationship – A plot of the monthly mean air and sea surface temperatures is shown in Figure 2.1-9. This shows the relationship between the two parameters. The air temperature is constantly modified during the year by the sea surface temperature. In general, during the winter, cold air moves off the continent over the relatively warmer water of the Grand Banks. In the spring, warm air moves northwards over the relatively cooler water on the Grand Banks. In the fall, the air and sea temperatures cool at a similar rate.

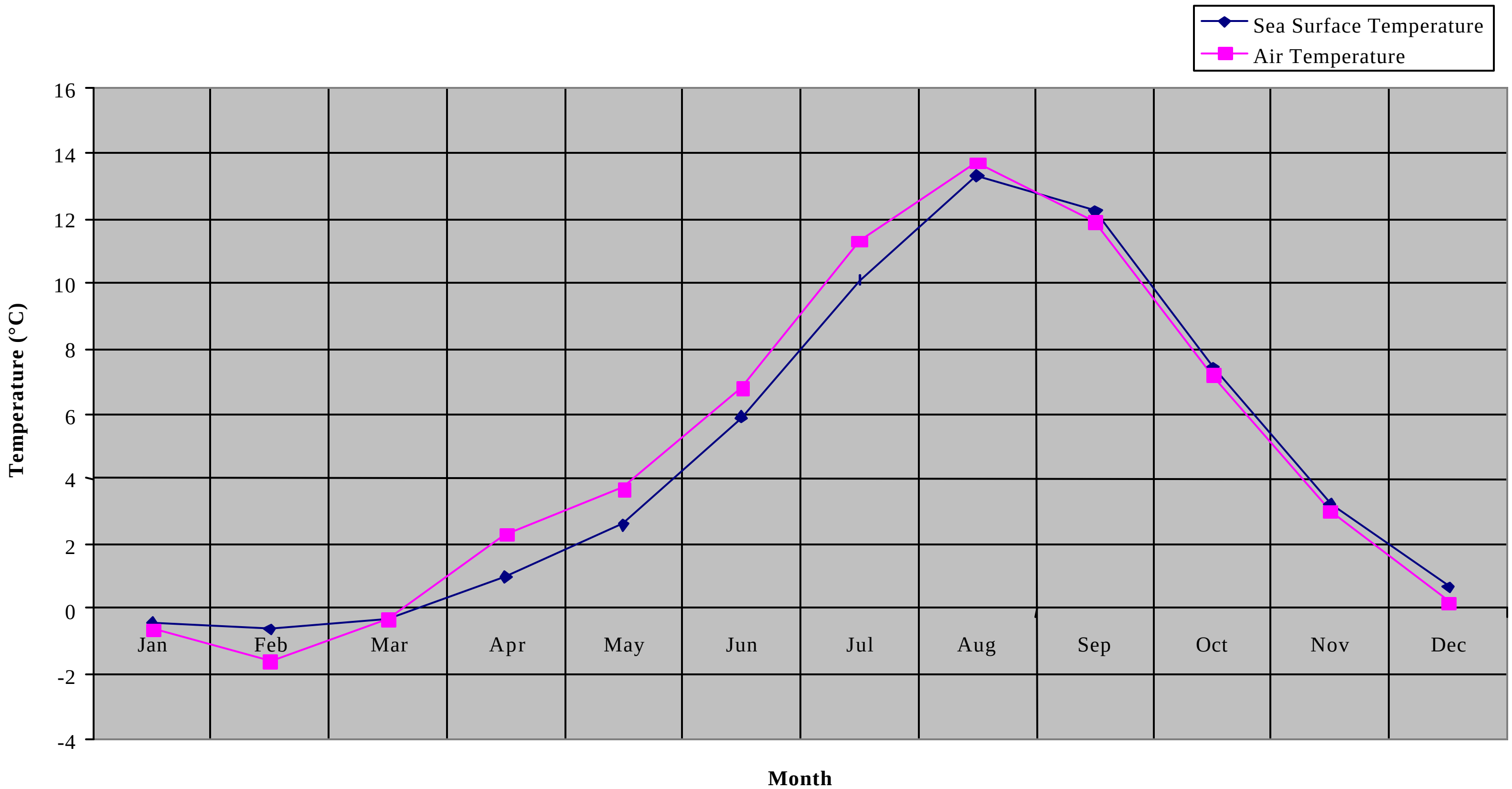
Most rig-related incidents to date for which there are complete and adequate reports indicate that icing in Canadian waters has generally been an occasional operational nuisance during the winter. No severe rig icing events have yet been recorded.

Figure 2.1–8 Monthly Air Temperature



Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Mar 99 to Oct 99).

Figure 2.1–9 Monthly Mean Sea Surface and Mean Air Temperature



Source: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).

2.1.13 St. John's Temperatures

The monthly statistics for the air temperature at St. John's Airport (from Environment Canada's Canadian Climate Normals) are shown in Table 2.1-10.

Table 2.1–10 St. John's Monthly Temperature Statistics

Month	Temperature (°C)		
	Minimum	Maximum	Mean
January	-23.3	15.2	-4.3
February	-23.8	15.6	-5.0
March	-23.8	18.3	-2.5
April	-14.8	24.1	1.3
May	-6.7	25.6	5.8
June	-3.3	29.4	10.9
July	-1.1	31.5	15.4
August	0.5	30.0	15.3
September	-1.1	27.8	11.6
October	-5.6	24.6	7.0
November	-12.6	19.4	3.1
December	-19.7	16.1	-1.7
Data Source: Canadian Climate Normals 1942 to 1990.			

2.1.14 Ice Accretion

According to the Supplementary Notes on Ice Accretion on Mobile Offshore Drilling Units (MODUs) in the MANMAR manual (Environment Canada 1982), ice accretion may be caused by the individual or combined occurrence of freezing spray, freezing precipitation, (wet) snow or deposition of super-cooled droplets in fog. Freezing spray is generally considered the most severe of these types of accretion.

Freezing spray commonly occurs on MODUs when air temperatures of approximately -4°C or less and wind speeds in the order of gale-force (34 kts (17.5 m/s)) or higher occur together. Sea surface temperatures of up to 6°C have been recorded during freezing spray conditions on a vessel.

The formation of an appreciable spray load on a MODU requires low air temperature and high wind conditions to persist for 12 or more hours. Most ice buildup from freezing spray is usually recorded below the main deck.

Most rig-related incidents to date, for which there are complete and adequate reports, indicate that icing in Canadian waters has generally been an occasional operational nuisance during the winter. No severe rig icing events have yet been recorded.

2.2 SEAS

2.2.1 Surface Wave Development and Propagation

2.2.1.1 Background Discussion

Surface waves at a point on the ocean are classified as being either wind (also sea) waves or swell. Wind waves are caused by the local wind and, in very basic terms, may be taken to be a function of the surface wind speed, the length of the fetch over which the wind is blowing and the duration of the event. Fetch is the length of the wave generation area and is limited by coastlines, surface fronts, curvature and difluence in the surface wind field (readily evident by the curvature and spreading of isobars on a surface weather map). Also, at times in the northwestern North Atlantic, fetch will be limited by the presence of sea ice.

When wind waves move out of the generating area, the waves are termed swell. The primary direction of swell energy propagation will be in the downwind direction of the winds in the generation area. Swell direction is defined operationally as the direction from which the swell is propagating. Swell direction is unrelated to the local wind direction. However, in a situation where the wind speed has decreased considerably, but the direction has remained unchanged, the waves that continue to propagate past the point will then be classified as a swell that is co-aligned with the wind direction.

Anytime that a point of interest lies in the downwind direction in a wave generation area, there is a likelihood that swell energy will reach the point at some time in the future. However, angular spreading and refraction (in relatively shallow water) of wave energy can act to alter the swell direction.

A sea state may be composed of the wind wave alone, swell alone, or the wind wave in combination with one or more swell trains. Standard synoptic marine weather observations allow for the inclusion of a wind wave group and up to two swell groups. Swell energy may reach a point from more than two directions at a particular time. Swell wave energy reaching a point may have been generated within the local weather system or from within distant weather systems located elsewhere over the ocean. The former situation typically arises when a front, trough, or ridge crosses the point of concern resulting in a marked wind shift.

Swell energy derived from within the local weather circulation system affecting the Grand Banks may arrive from essentially any direction in accordance with the orientation of the surface pressure and wind fields. The frequency of occurrence of such swell directions follows, to a large degree, the frequency of occurrence of wind directions at the point of concern. The direction of swell energy arriving from remote sources is governed by the synoptic climatology of the North Atlantic Ocean. Swell from distant sources is frequently reported to be from the south-southeast through southwest, and from the northwest through northeast. Less frequently, a swell generated at a distance reaches the Grand Banks from the east to southeast.

2.2.2 Wave Development and Propagation

This section contains a very brief outline of the nature of wind waves in a generation area where there is no swell present. As the wind begins to blow over a calm sea, a stress or horizontal force is applied to the sea surface. Momentum is transferred to the sea surface and surface waves begin to form. Small at first, waves increase in height and period as the wind speed increases. The appearance of wind waves is rather chaotic, with height, period and shape varying randomly. The mean direction is in the downwind direction, but wave buoy records show wind waves to be random in height and period.

A spectral analysis of wind waves shows that the wave energy is distributed across a band of frequencies or wave periods in a continuous single-peak spectrum. Concurrently, the peak frequency decreases with time.

Wind waves continue to grow unless limited by the available fetch or, with unlimited fetch, until such time that the amount of wind energy imparted to the waves is equal to the wave energy that is dissipated in turbulence and friction by breaking waves. At such time, the sea is said to be fully developed and the area under the spectral curve will be at a maximum for the prevailing wind conditions.

Definitions are provided in the following sections.

2.2.3 Simple Waves

The following definitions are used to describe simple waves (MANMAR Manual, Environment Canada 1996):

- Length (L): expressed in m, is the horizontal distance between two successive crests, or troughs.
- Height (H): expressed in m, is the vertical distance between the top of a crest and the bottom of the trough on either side.
- Speed (C): expressed in kts, is the speed at which individual waves travel.
- Period (T): expressed in seconds, is the time interval required for the passage of successive crests (or troughs) past a fixed point.

There are some useful theoretical relationships that have been checked by observation for simple waves. Approximate values can be calculated using the following equations:

- Length = 1.56 x Period = 0.17 x Speed
- Speed = 3 x Period = 2.43 x Length
- Period = 0.76 x Length = 0.33 x Speed

Although simple waves are never observed at sea, these equations can be used to obtain rough estimates for ocean waves.

Unlike the length and speed, the wave height bears no definite relationship to the wave period. However, it is found that the height of a wave seldom exceeds 1/13 of its length, otherwise the wave will break at the crest, forming "white horses". The ratio H/L is called the "steepness" of the wave, and cannot exceed approximately 1/13. The limiting value of the steepness explains why the maximum height of the sea waves is roughly in proportion to their length.

2.2.4 Wind Waves

A "wind wave" (also referred to as "sea wave") is the wave disturbance raised by the wind blowing at the vessel at the time of the observation (MANMAR Manual, Environment Canada 1996). Wind waves run in a direction within 10° or so of the wind blowing in the vicinity of the ship. The height of the wind waves is determined by the distance over which the wind has acted on the water in the same direction (called fetch), the average wind speed over the fetch, and the length of time the wind has been blowing. The height of wind waves varies from 1/13 to approximately 1/35 of their length.

2.2.5 Swell

A swell is a wave system not raised by the local wind blowing at the time of the observation, but raised at some distance away due to winds blowing there, and which has moved to the vicinity of the vessel (MANMAR Manual, Environment Canada 1996). Swell waves travel out of a stormy or windy area and continue on in the direction of the winds that originally formed them as wind waves. The swell may travel for thousands of miles before dying away. As the swell wave advances, its crest becomes rounded and its surface smooth. Its length increases until it is approximately 35 to 200 or more times its height.

Swell waves normally come from a direction different from the prevailing wind at the time of the observation. However, wind waves and swell waves may occasionally be seen coming from essentially the same direction, thus making it more difficult to distinguish the two systems, especially if the wind waves are high.

The swell direction is the direction from which the waves are coming. The direction is determined with reference to true north, and is recorded to the nearest 10°.

2.2.6 Cross Swells

Wind waves and one or more systems of swell waves are frequently present at the same time, forming "cross swells" (MANMAR Manual, Environment Canada 1996). A cross swell is determined to be present if the primary swell (greater than 0.25 m in height) has an approximate direction between 45° and 135° from the reported wind direction. A following swell is determined to be present if the primary swell (greater than 0.25 m in height) direction is between approximately 0° and 45° from the reported wind direction. For an opposing swell, the swell direction is between 135° and 180° from the reported wind direction.

2.2.7 Wave Groups

Waves generally travel in groups, with large well-formed waves at the centre of each group, and patches of relatively dead water between the groups. According to the WMO Guide to Wave Analysis and Forecasting (WMO 1988), these groups advance at their own velocity or "group velocity". For deep water waves the group velocity = ½C (the average speed of individual waves). The wave groups can be considered as carriers of the wave energy, so the group velocity is also the velocity with which the wave energy is propagated.

2.2.8 Significant Wave Height

The following definitions are from the WMO Guide to Wave Analysis and Forecasting (WMO 1988). The significant wave height is defined as the average height of the highest one-third of individual waves typically observed for a period of 20 min. The value of the significant wave height approximates to the visually observed wave height.

When different wave trains (for example sea and swell or several swells) are merged, the heights do not combine linearly. Wave energy is related to the square of the wave height and it is the energy that is additive. Consequently, when two or more wave trains are combined, the resultant height is determined from the square root of the sum of the squares of the separate trains, expressed as:

- Combined Significant Wave Height = $\sqrt{(\text{Wind Wave})^2 + (\text{Swell 1})^2 + (\text{Swell 2})^2}$

The significant wave height is referred to in this section as the "combined significant wave height" to make it clear that this height is a combination of both wind waves and swells.

2.2.9 Wave Period

In MANMAR coded observations, the average value of the periods of the larger well-formed waves near the centre of the wave groups are reported. In the AES40 data series and the Hibernia nine-yr data series, the peak period is taken as the reciprocal of the peak frequency of the total wave spectrum.

2.2.10 Wave Height Exceedance

Figures in Appendix 2.C show the percentage exceedance of the combined significant wave height for each month of the year. Data from all four data sets have been used in the graphs.

2.2.11 Maximum Combined Significant Wave Height

The maximum combined significant wave height for each month from the AES40, Hibernia and Husky Oil data sets are shown in Table 2.2-1. Values from the COADS data have not been included due to some large errors in coding wave heights by vessels. The Hibernia and Husky Oil values in Table 2.2-1 are actual reported heights. The AES40 values have been produced by a wave model.

Table 2.2–1 Monthly Maximum Combined Significant Wave Heights (m)

Month	Data Base		
	AES40	Hibernia	Husky Oil
January	13	10.2	10
February	13.7	11.4	10.4
March	10.1	9.1	8.3
April	10.8	8.9	8.1
May	10.1	6.4	7.1
June	9	5.2	6.5
July	6	6.2	6.1
August	5.8	5.8	5.6
September	9	7.9	9.7
October	11.1	7.3	7.4
November	11.6	11.5	11.3
December	13.4	12.8	12.5

Data Source: AES40 grid point 5622 data 1958 to 1997.
Hibernia 9-yr data series 1980 to 1988.
Husky Oil/Bow Valley Grand Banks data 1984 to 1988.
Husky Oil White Rose data 1999.

2.2.12 40-Year Variability

The mean combined significant wave height for each month over a 40-yr period (from the AES40 hindcast data set) are shown in Figures 2.2-1 to 2.2-4. Wave heights have not been calculated for the times when the grid point was covered by 50 percent or more sea ice. This accounts for gaps in the time series plots.

2.2.13 Cross Swells

Depending on the month, approximately 50 to 80 percent of all the MANMAR observations in the Husky Oil data set containing wave information included a primary swell of greater than 0.25 m. Depending on the month, approximately 30 to 50 percent of all the MANMAR observations in the Husky Oil data set containing wave information included a cross swell. This information is displayed in Table 2.2-2.

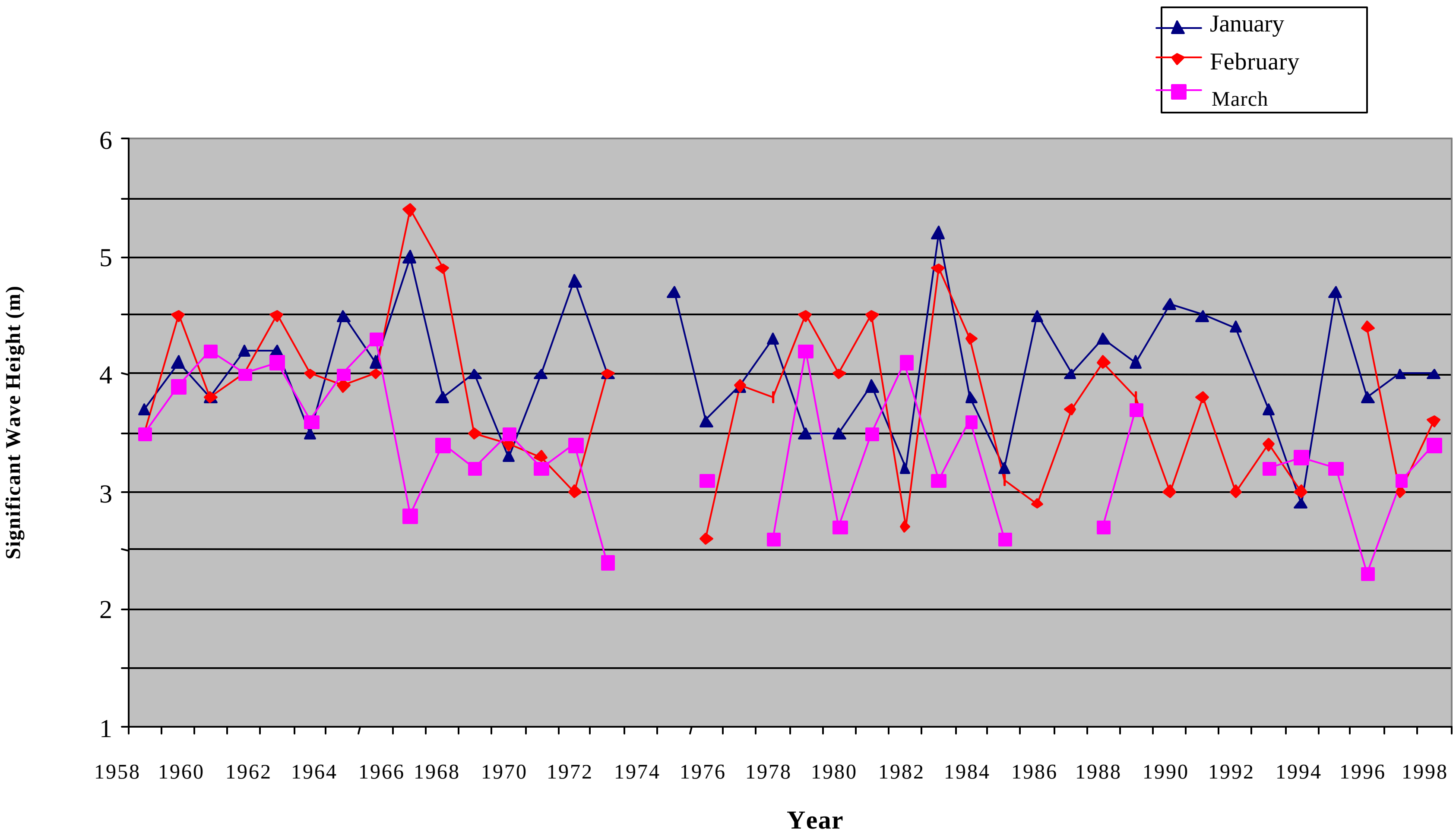
Table 2.2–2 Percentage Occurrence of Primary Swell (>0.25m) Relative to Wind Direction

Month	Cross[1] Swell	Following[2] Swell	Opposing[3] Swell	Total
January	35.2	19.3	14.6	69.1
February	49.3	18.1	11.2	78.6
March	40.4	24.3	10.5	75.3
April	38.5	14.2	14.6	67.3
May	35.2	18.6	16.6	70.4
June	32.8	20.5	15.5	68.7
July	29.7	20.6	7.4	57.6
August	29.8	10.5	12.7	53.0
September	36.2	15.8	17.7	69.7
October	45.1	17.6	14.6	77.3
November	41.8	13.9	21.7	77.4
December	42.5	17.3	16.1	75.8

Data Source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (June 99 to Oct 99).

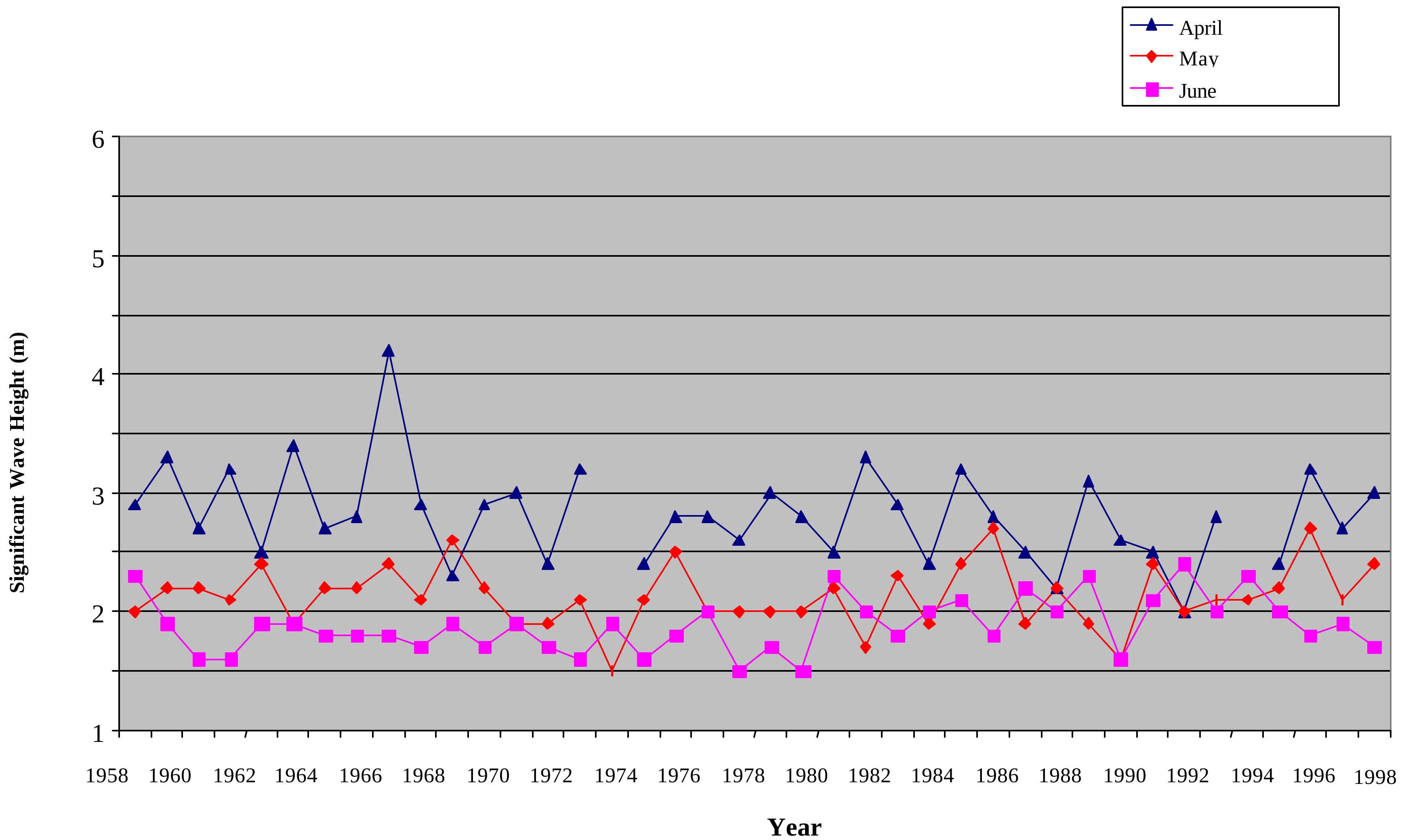
Notes: [1] Cross Swell: when Primary Swell (>0.25 m) is between 45° to 135° (plus or minus) from the Wind Direction
[2] Following Swell: when Primary Swell (>0.25 m) is between 0° to 45° (plus or minus) from the Wind Direction
[3] Opposing Swell: when Primary Swell (>0.25 m) is between 135° to 225° from the Wind Direction

Figure 2.2–1 Mean January, February and March Significant Wave Height



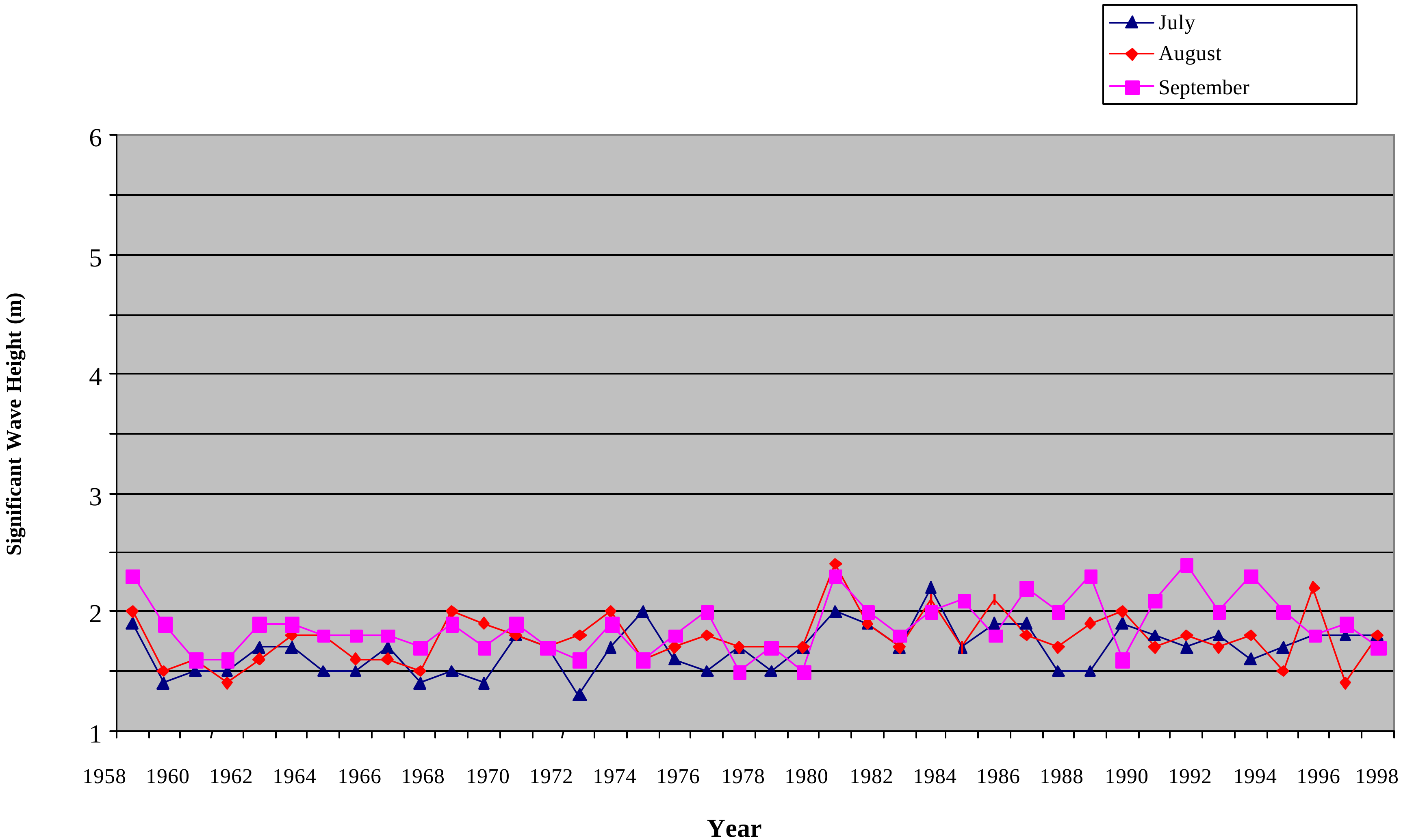
Source: AES grid point 5622 data, 1958 to 1997.

Figure 2.2–2 Mean April, May and June Significant Wave Height



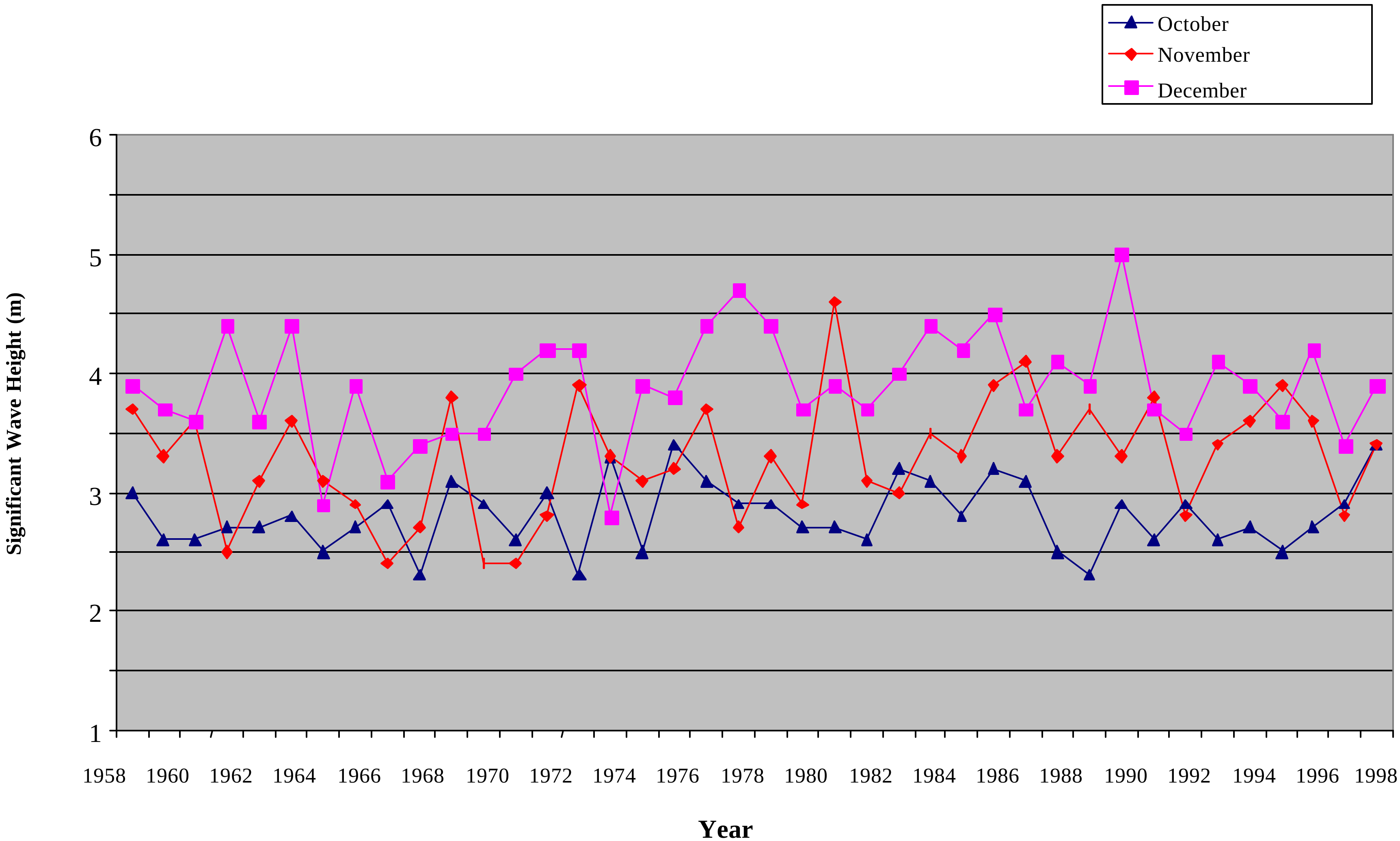
Source: AES grid point 5622 data, 1958 to 1997.

Figure 2.2–3 Mean July, August and September Significant Wave Height



Source: AES grid point 5622 data, 1958 to 1997.

Figure 2.2–4 Mean October, November and December Significant Wave Height



Source: AES grid point 5622 data, 1958 to 1997.

2.2.14 Period

The general trend of higher wave periods in the winter than in the summer is shown in Tables 2.2-3 to 2.2-5. A plot of the Hibernia data in Figure 2.2-5 shows smaller peaks in the peak period for all months at 14 s and for the months August through to March at 17 s.

Table 2.2–3 Percentage Occurrence of Peak Wave Period (Hibernia Data)

Month	Peak Wave Period (s)																				Total Reports
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January	0.0	0.0	0.0	0.0	0.7	3.4	5.7	6.1	11.2	18.9	**25.0**	13.6	5.9	6.7	2.2	0.2	0.5	0.0	0.0	0.0	2,232
February	0.0	0.5	0.0	0.1	0.9	2.7	7.5	7.6	10.1	**33.9**	17.1	0.0	0.0	4.1	1.9	0.0	0.1	0.0	0.0	0.0	2,040
March	0.0	0.0	0.1	0.2	0.6	2.4	5.9	7.4	7.0	**27.6**	26.6	12.2	0.0	5.5	1.6	0.0	0.1	0.0	0.0	0.0	2,232
April	0.0	0.0	0.0	0.1	0.6	1.9	4.4	8.9	18.5	**31.5**	17.9	7.7	1.9	4.9	1.4	0.2	0.0	0.0	0.0	0.0	2,160
May	0.0	0.0	0.0	0.1	1.1	3.1	6.7	13.4	**32.2**	16.2	16.7	6.0	1.9	1.9	0.7	0.0	0.0	0.0	0.0	0.0	2,232
June	0.0	0.0	0.0	0.3	2.0	6.9	11.6	24.1	**30.1**	11.1	9.9	2.5	0.1	1.0	0.3	0.0	0.0	0.0	0.0	0.0	2,160
July	0.0	0.0	0.0	0.9	2.7	6.4	19.9	**33.8**	18.3	9.6	6.6	1.1	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	2,232
August	0.0	0.0	0.0	0.3	2.8	9.5	16.1	**23.1**	19.7	12.1	9.4	4.0	0.7	1.1	0.7	0.0	0.4	0.0	0.0	0.0	2,232
September	0.0	0.0	0.0	0.8	1.2	4.3	6.9	12.8	19.5	**20.3**	16.7	8.8	3.1	3.7	1.5	0.1	0.1	0.0	0.0	0.0	2,160
October	0.0	0.0	0.0	0.2	0.4	1.7	5.0	7.5	10.3	14.2	**29.7**	11.4	4.5	7.9	4.2	1.0	1.5	0.2	0.0	0.1	2,232
November	0.0	0.0	0.0	0.1	0.2	1.2	3.9	5.1	10.2	17.5	**26.7**	15.6	7.2	8.1	3.3	0.0	0.6	0.2	0.0	0.0	2,160
December	0.0	0.0	0.0	0.0	0.0	0.7	1.7	4.3	6.9	14.2	**35.9**	14.8	6.6	8.1	4.0	0.6	1.9	0.2	0.0	0.0	2,232

Data source: Hibernia 9-yr time-series 1980-1988.

Note: Figures highlighted in bold are the highest monthly percentage

Table 2.2–4 Percentage Occurrence of the Peak Wave Period (AES40 Data)

Month	Peak Wave Period (s)																				Total Reports
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January	0.0	0.0	0.0	0.0	0.4	1.6	5.4	8.5	13.9	16.7	**18.4**	15.8	10.8	4.9	1.0	0.1	0.0	0.0	0.0	0.0	4,959
February	0.0	0.0	0.0	0.0	0.8	3.0	7.0	8.9	13.0	16.3	**17.1**	0.0	0.0	4.1	1.0	0.3	0.0	0.0	0.0	0.0	4,520
March	0.0	0.0	0.0	0.1	1.0	2.5	6.7	7.8	11.6	**15.6**	14.7	11.0	0.0	2.2	0.6	0.3	0.0	0.0	0.0	0.0	4,960
April	0.0	0.0	0.0	0.0	0.9	3.5	8.6	12.6	20.1	**21.3**	15.0	7.2	3.1	2.0	0.3	0.0	0.0	0.0	0.0	0.0	4,801
May	0.0	0.0	0.0	0.2	2.4	7.5	18.3	**24.7**	22.7	12.9	7.0	2.5	1.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	4,960
June	0.0	0.0	0.0	0.2	3.9	11.9	**25.3**	24.3	20.2	8.9	2.8	1.2	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	4,800
July	0.0	0.0	0.0	0.2	4.7	16.4	**32.3**	20.5	14.0	6.7	2.4	0.8	0.8	0.4	0.3	0.3	0.1	0.0	0.0	0.0	4,960
August	0.0	0.0	0.0	0.3	5.3	15.1	**32.0**	22.1	12.6	6.4	3.8	1.5	0.5	0.4	0.0	0.1	0.0	0.0	0.0	0.0	4,960
September	0.0	0.0	0.0	0.1	1.9	7.5	**21.7**	20.1	17.9	12.1	9.1	4.5	3.5	1.3	0.3	0.1	0.0	0.0	0.0	0.0	4,800
October	0.0	0.0	0.0	0.1	0.8	4.3	12.3	18.0	**21.6**	17.7	11.9	6.9	3.9	1.8	0.6	0.1	0.0	0.0	0.0	0.0	4,960
November	0.0	0.0	0.0	0.1	0.7	3.0	8.5	12.6	18.0	**21.8**	16.1	9.1	6.6	2.8	0.5	0.1	0.0	0.0	0.0	0.0	4,800
December	0.0	0.0	0.0	0.0	0.3	1.3	4.5	8.2	15.5	21.6	**19.9**	14.2	9.1	4.3	0.9	0.2	0.0	0.0	0.0	0.0	4,960

Data source: AES40 grid point 5622 data (1958 to 1997).

Note: Figures highlighted in bold are the highest monthly percentage

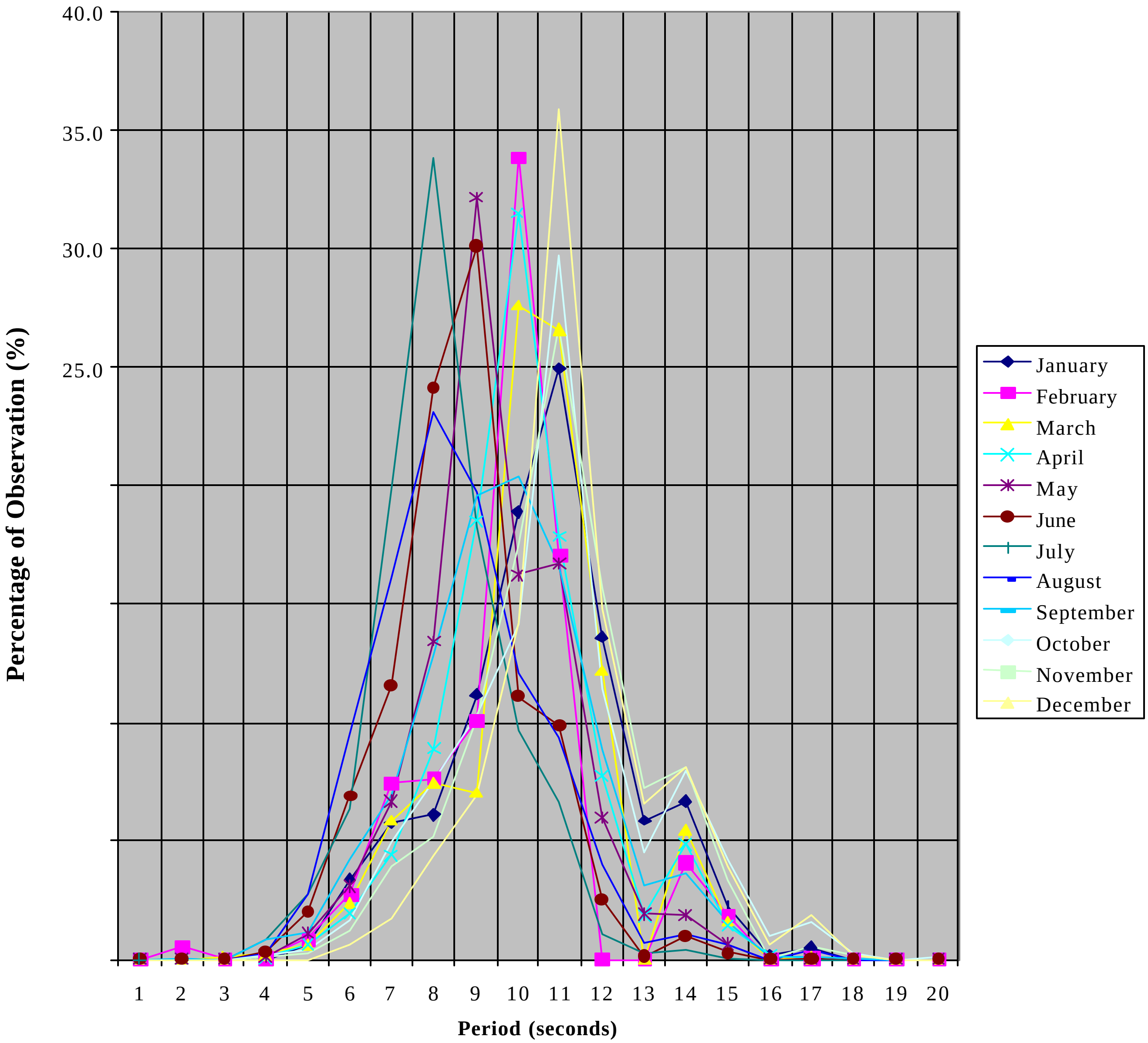
Table 2.2–5 Percentage Occurrence of Highest Average Wave Period Reported in Each Observation (Husky Oil Data)

Month	Wave Period (s)																	Total Reports
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
January	0.2	0.1	0.0	0.0	0.2	3.1	10.0	29.5	**31.5**	18.8	5.2	1.2	0.2	0.1	0.0	0.0	0.0	1,763
February	0.0	0.0	0.0	0.1	0.0	2.3	13.9	**31.5**	31.0	15.3	5.9	0.0	0.0	0.0	0.0	0.0	0.0	877
March	0.2	0.0	0.0	0.5	0.9	3.9	14.8	**35.7**	25.1	16.1	2.2	0.6	0.0	0.0	0.0	0.0	0.0	1,039
April	0.1	0.1	0.0	0.0	0.0	2.1	12.5	22.4	**25.7**	22.6	6.4	3.8	3.8	0.4	0.0	0.1	0.0	1,120
May	0.3	0.0	0.2	0.4	1.5	9.9	21.4	**36.8**	17.4	9.0	2.1	0.7	0.2	0.0	0.0	0.0	0.0	1,469
June	0.1	0.1	0.3	3.9	8.0	12.8	23.3	**36.7**	9.6	3.4	1.0	0.5	0.3	0.0	0.0	0.0	0.0	1,459
July	0.3	0.2	0.1	0.6	4.9	13.9	20.7	**36.3**	14.7	6.5	1.0	0.5	0.3	0.1	0.1	0.0	0.0	1,968
August	0.5	0.1	0.3	2.8	4.9	9.7	17.2	**30.5**	26.5	6.1	0.9	0.5	0.1	0.0	0.0	0.0	0.0	1,815
September	0.1	0.1	0.0	0.0	0.5	8.3	17.8	**40.9**	20.1	9.5	2.3	0.2	0.0	0.0	0.0	0.0	0.0	1,678
October	0.3	0.0	0.0	0.4	0.8	3.1	16.6	**35.3**	28.0	10.7	3.1	1.3	0.5	0.0	0.0	0.0	0.0	1,588
November	0.3	0.0	0.0	0.2	0.3	3.9	7.9	25.0	**35.9**	21.7	3.2	1.5	0.0	0.0	0.0	0.0	0.0	1,422
December	0.1	0.0	0.0	0.1	0.5	2.0	7.3	20.4	28.3	**30.3**	8.6	2.4	0.1	0.0	0.0	0.0	0.0	1,484

Data source: Husky Oil/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88).
Husky Oil White Rose Environmental Data (Jun 99 to Oct 99).

Note: Figures highlighted in bold are the highest monthly percentage

Figure 2.2–5 Percentage Occurrence of Peak Wave Period



Source: Hibernia nine-yr time series 1980 to 1988.

2.2.15 Breaking Waves

Waves break when the water particle velocity at the wave crest exceeds the propagation speed of the wave. As a wave breaks it will dissipate part of its energy.

Mason (1952) observed two main types of breaking waves in deep water. He observed plunging breakers in which the wave crest curls forward and plunges deeply into the forward slope of the wave, and the more common spilling breakers in which the broken water spills more gently into the forward slope as a quasi-steady whitecap.

In laboratory experiments, Kjeldsen and Myrhaug (1978; 1979) identified three types of breakers; a spilling breaker, a deep water bore, and a plunging breaker. The spilling breaker is always characterized by the wave breaking at the top of the crest and fluid elements sliding down the leading slope. When breaking is vigorous, an extensive whitecap is seen, in which air is entrained into the spilled water (LeBlond 1982). The deep-water bore appears as a highly nonlinear wave-wave interaction, wherein one wave overtakes another. Deep water plunging breakers results from strong highly nonlinear interactions of several waves in a wave train, and in interactions with opposing currents. They are characterized by a foam zone covering up to one-third of the total wave height, over which air entrainment occurs.

The sea criterion for the Beaufort wind scale states that for wind force 2 and below waves do not break. For wind force 3 (7 to 10 kts) the wave criterion includes some scattered whitecaps. At Beaufort wind force, numerous whitecaps are observed.

2.3 OCEANIC ENVIRONMENT

2.3.1 Water Circulation

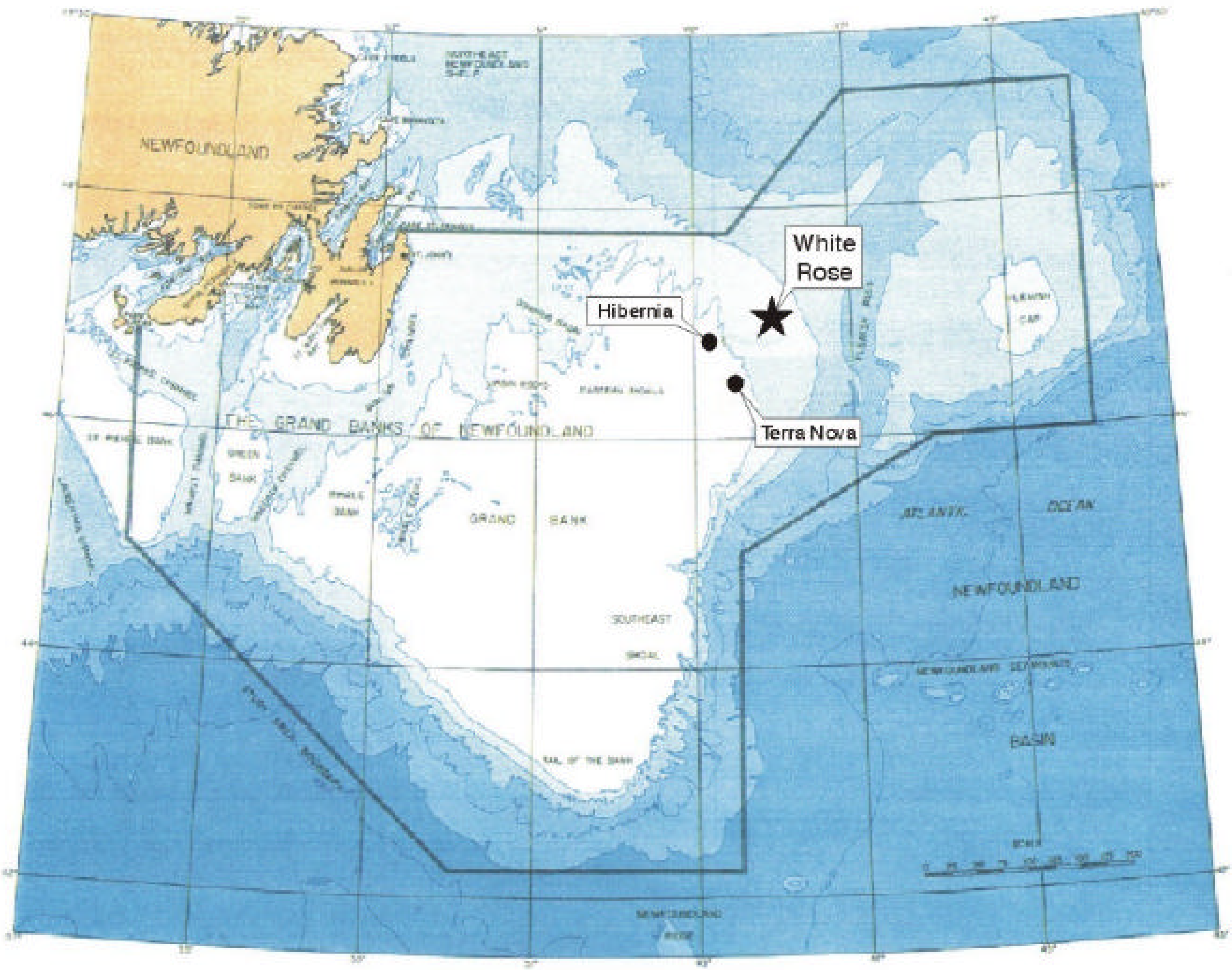
The regional oceanic circulation on the Grand Banks and surrounding areas is governed by the bathymetric features of the continental shelf. A major characteristic of ocean currents is their tendency to follow local and regional underwater bathymetry (contours).

The Grand Banks–Flemish Cap bathymetric features (Figure 2.3-1) exert a major influence on the regional oceanic circulation. The shape of the banks and channels steers the flow of the Labrador Current. The Labrador Current is comprised of two main streams; an inshore stream near the coast, and a more intense offshore stream over the shelf break between the 400 and 1200 m isobaths (Lazier and Wright 1993). There is some exchange between these two streams which occurs in the channels and saddles that separate the banks offshore Labrador and Newfoundland. The inshore branch of the Labrador Current flows through Avalon and Haddock Channels, while the offshore branch flows along the northern slope of the Grand Banks before turning south through Flemish Pass. A component of the offshore branch continues eastward and flows around the eastern side of Flemish Cap.

Another major current system is situated to the south of the Grand Banks. The Gulf Stream, a major western boundary current, departs the shelf break near Cape Hatteras (USA) at approximately 75°W flowing northeast. In the area of the Southeast Newfoundland Rise, which runs from the Tail of the Grand Banks toward the mid-Atlantic Ridge, the Gulf Stream branches into two streams. The southern branch continues east at approximately 40°N. The northern branch, known as the North Atlantic Current, turns north and runs along the east side of the Grand Banks and Flemish Cap, continues into the Northwest Corner at approximately 51°N, 44°W, and then turns east following approximately 50°N latitude. Krauss et al. (1990) found the North Atlantic Current to be approximately 300 km wide. Near the Tail of the Grand Banks, the North Atlantic Current comes into contact with the Continental Slope and follows it northeast around Flemish Cap. In this area, it also meets the Labrador Current flowing south. The entire area of the southeastern Grand Banks is a massive mixing area between two water masses with very different temperature and salinity characteristics. A secondary eastward current also flows inshore of the Atlantic Current along the Continental Slope, sometimes referred to as the Slope Current, with characteristics of Slope Water (McLellan 1957). Slope Water is formed from Atlantic current water and coastal water.

White Rose is at the northeast sector of the Grand Banks (Figure 2.3-2) and is located in a water depth of approximately 120 m. In the immediate area, the bottom relief is relatively featureless, but steep slopes occur to the north and east at the edge of the Grand Banks. White Rose is located inshore of the Labrador Current, where most of the time the flow is weak, with variable mean flows, compared to the strength of the two major current systems in the vicinity. The variabilities in the mixing and interactions created by these two major current systems can, at times, have an effect on the current flow at White Rose.

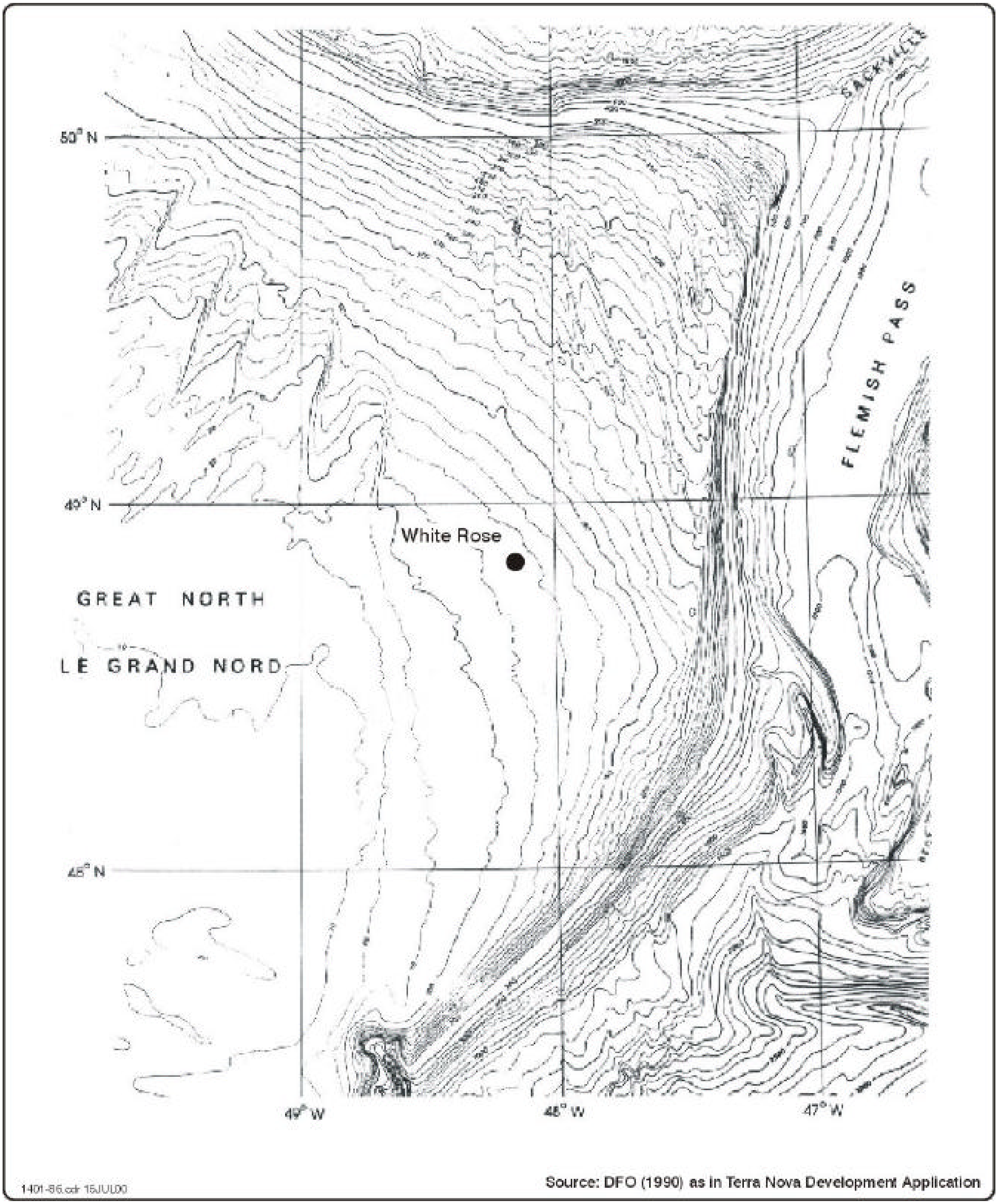
Figure 2.3–1 Grand Banks and Flemish Cap Bathymetric Features



1401-85.CDR 15JUL00

Source: Mobil (1985)

Figure 2.3–2 Bathymetric Chart of the White Rose Area



2.3.2 Data Base

The main oceanographic data bases are maintained by three DFO agencies: The Bedford Institute of Oceanography (BIO) in Dartmouth, MEDS in Ottawa, and the Northwest Atlantic Fisheries Centre in St. John's.

BIO is the regional current meter data archive centre for the Canadian East Coast. All current meter data collected both by government agencies and the oil industry are available. They have also carried out many oceanographic studies of the Grand Banks region. The majority of the available current meter data for the White Rose area were collected by Husky Oil during periods of exploration drilling. The data have been traditionally collected at water depths of 20 m below surface, mid-depth, and 10 m above bottom.

Oceanographic data (except moored current meter data) are available from archives at the MEDS and maintained in databases at the BIO and at the Northwest Atlantic Fisheries Centre. Most of the hydrographic data collected before the late 1970s were collected at standard oceanographic depths (0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, and 400 m) using water sampling bottles fitted with reversing thermometers (Colbourne and Foote 1994). Since the 1960s to the present, temperature data have been collected using mechanical and electronic bathythermographs. Since the late 1970s, conductivity–temperature–depth (CTD) recorders have been most commonly used. There are more hydrographic data available for White Rose than most areas on the Grand Banks because White Rose is located on the Flemish Cap transect. Data going back to 1931 are available, sampled at standard stations on the Flemish Cap transect and from fisheries assessment surveys.

The International Ice Patrol (IIP) of the U.S. Coast Guard has assembled a mean current data base (known as the IIP database) for the Grand Banks that it uses to predict iceberg drift. The basis of the mean current field was hydrographic data collected during 100 surveys from 1934 to 1978 (Murphy et al. 1991). Geographic currents were calculated from known density gradients. In 1976, the IIP began a drifting buoy program to measure surface currents during the spring iceberg seasons. Between 1989 and 1990, the IIP database was revised to include all of their drifting buoy data. Since 1990, the database has been updated regularly as additional drifting buoy data became available.

In addition to the IIP data on the Grand Banks, drifting buoy data have also been collected by BIO and by the Northwest Atlantic Fisheries Centre. DFO drifter track data can be obtained from the MEDS in Ottawa.

Oceanographic modelling is carried out by the BIO, the Northwest Atlantic Fisheries Center, and the Departments of Oceanography of both Dalhousie and Memorial Universities. The Coastal Oceanography Group at BIO operates a current model of the Grand Banks, which can be run on a daily basis.

2.3.3 Water Characteristics

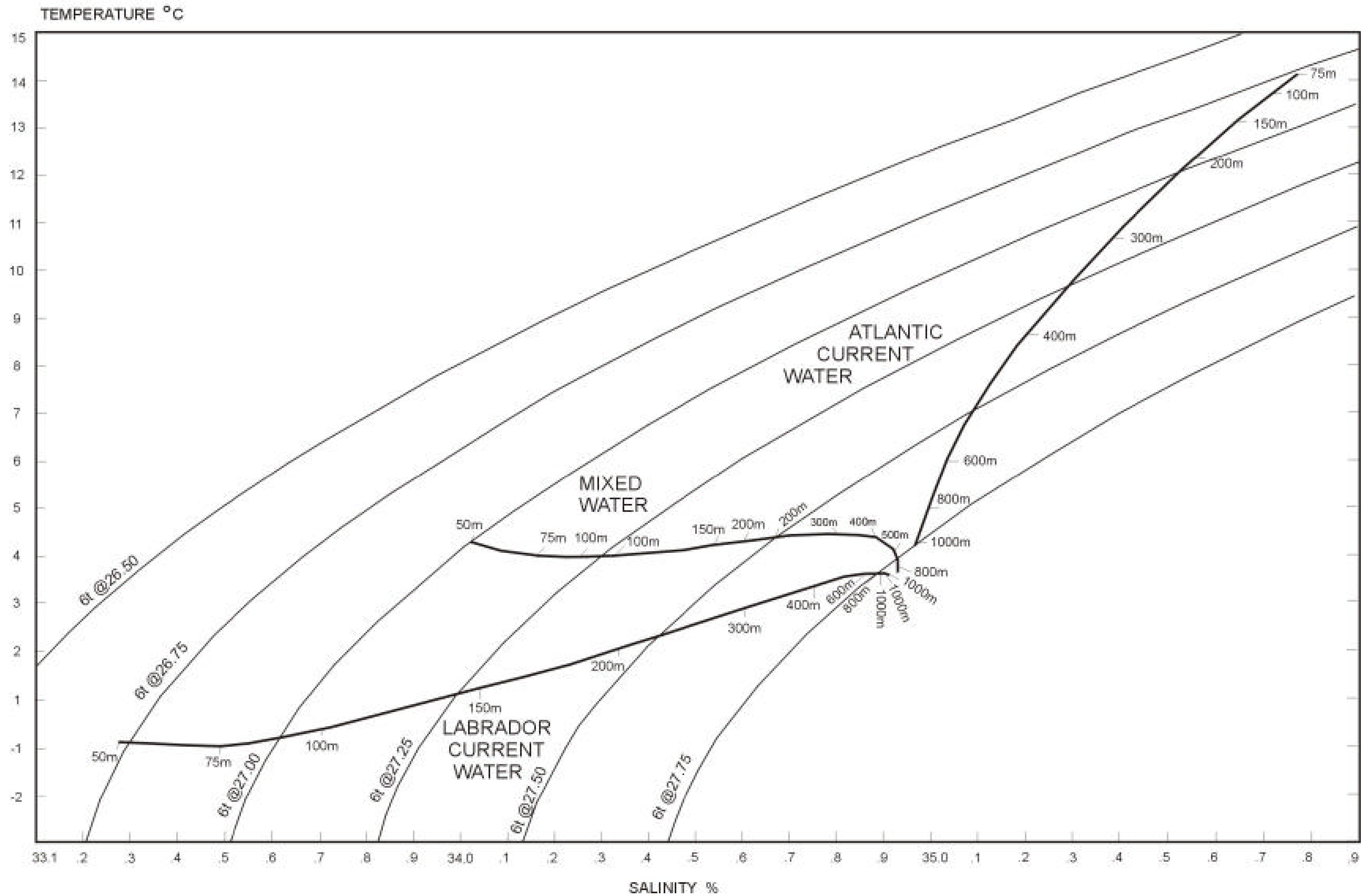
The water characteristics at White Rose can be expected to show yearly variations depending on the strength and position of the North Atlantic Current. As previously explained (Section 2.3.1), the northern branch of the Gulf Stream, known as the North Atlantic Current, usually turns north along the east side of the Grand Banks and Flemish Cap, and then turns east at approximately 50°N. Krauss et al. (1990) found that approximately two-thirds of the volume transport of the Gulf Stream continues as the North Atlantic Current. White Rose is located at approximately 47°N, but more importantly, it is the position of the inshore boundary of the Atlantic Current between 43°N and 46°N, together with the Labrador Current, which would have the most influence on the water properties at White Rose. The Labrador Current flows southward along the edge of the Grand Bank, through Flemish pass and around Flemish Cap.

The water mass characteristics created by these two current systems are described below:

- cold (<4°C), low salinity water (<34 parts per thousand (‰)) originating on the continental shelf off Labrador and further north and transported into the area by the Labrador Current;
- further offshore, warm (7°C-18°C), high salinity (>35‰) Western North Atlantic Central water of the North Atlantic Current;
- mixed intermediate water formed when the warm and high salinity water of the North Atlantic Current comes into contact with the cold low salinity water of the Labrador Current on the southern and eastern slope of the Grand Banks (Figure 2.3-3); and
- Slope Water is formed South of the Grand Banks from Atlantic Current water and coastal water. The coastal water consists of a mixture of Slope Water and Labrador Current water. Slope Water has characteristics similar to Atlantic water but with a slightly lower salinity (Figure 2.3-4).

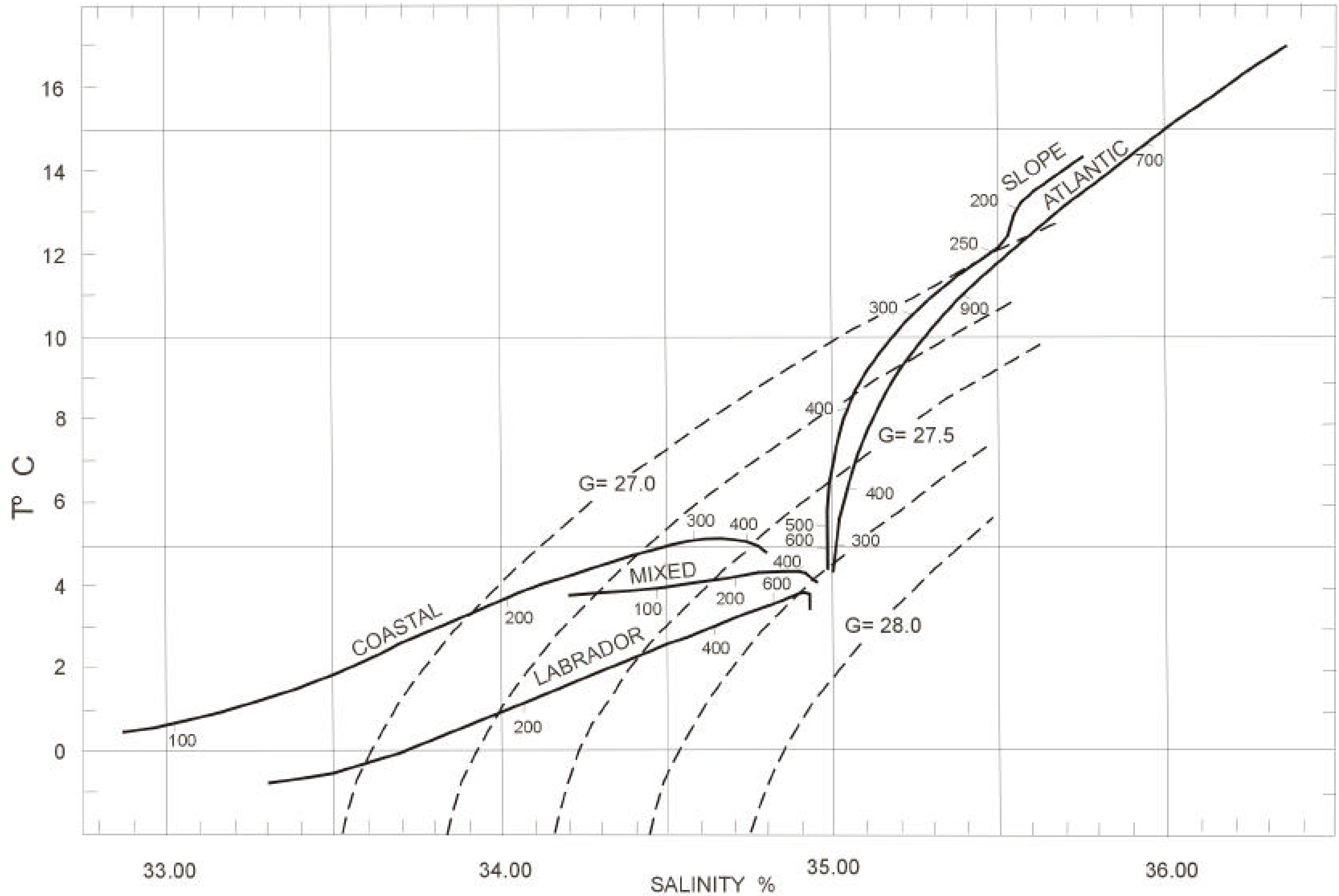
DFO has been measuring the hydrographic properties of the waters offshore Newfoundland and Labrador for many years along standard transects, which run perpendicular to the coast. One of these transects runs along 47°00´N from the Newfoundland Coast to 42°00´W. This transect (the Flemish Cap transect) runs directly across the study area. Therefore, there are more hydrographic data available for White Rose than most other regions on the Grand Banks. The earliest known single observation along the Flemish Cap transect occurred in July 1910 (Colbourne et al. 1996). From 1931 to 1950, many observations were made, but the first complete transect was carried out in 1951. Since 1951, the transect has been occupied on a regular basis in July or August by DFO. Observations along the transect during other months, particularly in the winter months, have been irregular.

Figure 2.3–3 Mean T-S Curves for Labrador Current Water, Atlantic Current Water and Mixed Water found in Grand Bank Region



Source: United States Coast Guard (1966)

Figure 2.3–4 T-S Curves for Five Water Masses Found Between the Gulf Stream and the Continental Shelf West of 45 Degrees West



Source: McLellan (1957)

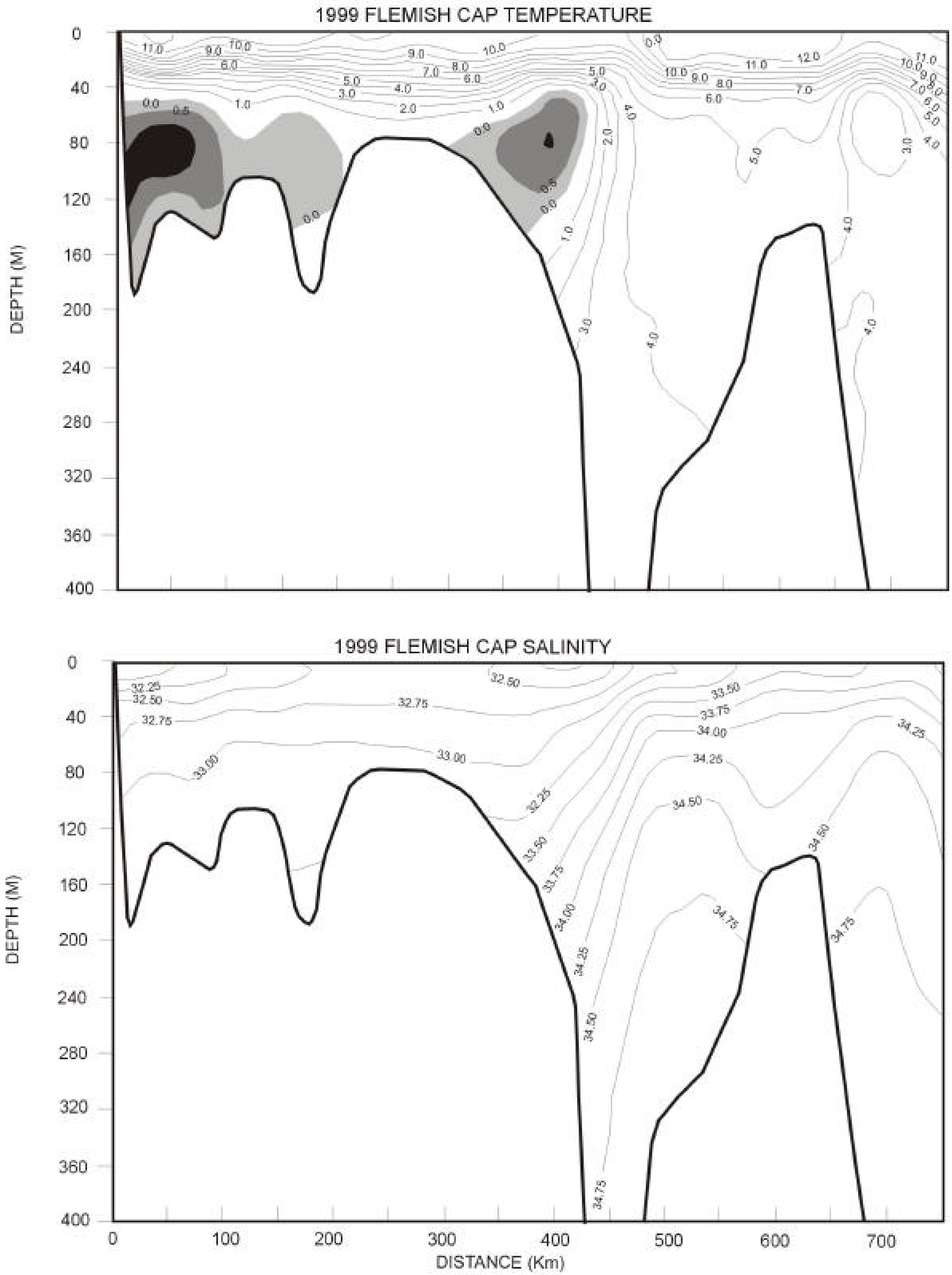
A dominant feature of the vertical temperature structure off the East Coast of Newfoundland on the Continental Shelf is the cold intermediate layer (Petrie et al. 1988). The cold intermediate layer occurs between 75 and 150 m, and is defined as the layer where the annual average temperature is <0°C (Petrie et al. 1991). On the Grand Banks, including White Rose, the cold intermediate layer would normally extend to bottom because of the shallow bathymetry.

Since hydrographic measurements began in the 1950s along the Flemish Cap transect, there have been three major cold periods; most of the 1970s, mid-1980s, and the late 1980s to early 1990s. Colbourne (2000) describes these anomalies as follows. "The cold period, beginning around 1971, continued until 1977 in the upper layer, while temperature anomalies in the 1970s below 100 m were insignificant. From 1978 to 1984, the temperature anomalies showed a high degree of variability in the upper water column with a tendency towards positive anomalies. By 1985, negative temperature anomalies had returned in the top 100 m of the water column. This cold period moderated briefly in 1987 but returned again by 1988 and continued into the early 1990s. From 1995 to 1998 temperatures moderated and were above normal during 1999".

Colbourne (2000) described the salinity anomalies during this period as being fresher than normal from 1971 to 1976 and from 1983 to 1986 in the upper 100 m of the water column. The trend in salinity during the early 1990s ranged from slightly above normal (32‰) at the surface to slightly below normal at deeper depths. In 1999, bottom temperatures over most of the Grand Banks were near 0.5°C above normal (Colbourne 2000). East of White Rose, the offshore waters were above normal. For instance, over the Flemish Cap temperatures were greater than 12°C at the surface and about 4 to 5°C at 80 m depth to the bottom. The vertical cross sections of temperature and salinity for summer 1999 are shown in Figure 2.3-5. At the White Rose location, OCEANS Ltd. measured maximum temperatures in August 1999 of 15.20°C at 20 m below the surface, 2.04°C at mid-depth and 0.04°C near the bottom. For comparison, the vertical cross-sections of temperature and salinity for the Flemish Cap transect for a typical year (1968) and a cold year (1971) are shown in Figures 2.3-6 and 2.3-7, respectively.

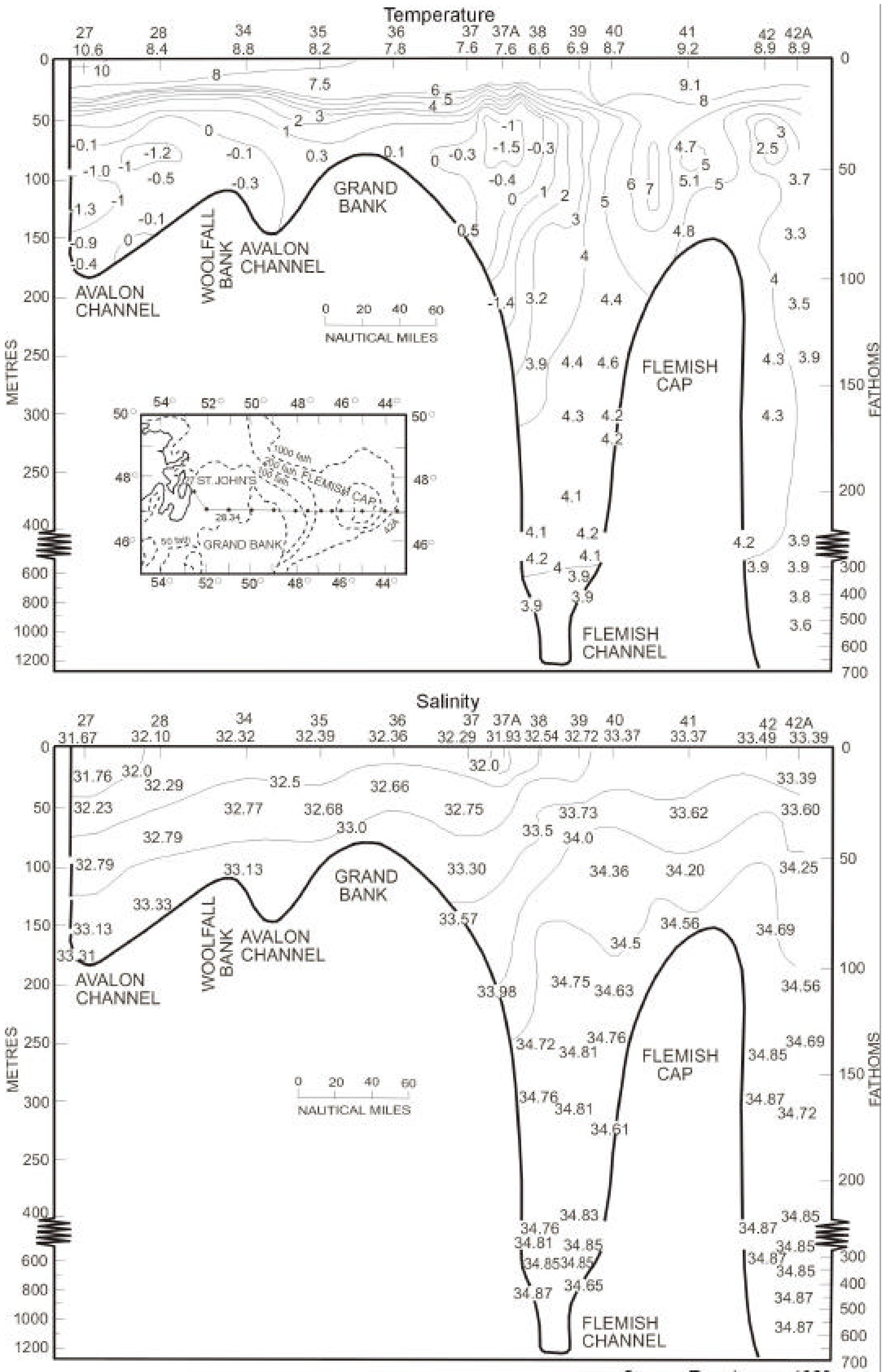
The spatial distribution of water properties offshore Newfoundland at 20 and 75 m is presented for July and January in Figures 2.3-8 and 2.3-9, respectively (Colbourne and Foote 1994). The warmer, high-salinity Slope Water is evident to the south and east of the Grand Banks at both 20 and 75 m depths. The large horizontal gradients mark the boundaries (oceanic fronts) between the cold low salinity water of the Labrador Current and coastal waters, and the warm high salinity Slope and Atlantic Current waters.

Figure 2.3–5 Vertical Cross-Sections of Temperature (EC) and Salinity (l) Along the Standard Flemish Cap Transect for the Summer of 1999



Source: Colbourne (2000)

Figure 2.3–6 Temperature (°C) Above and Salinity (l) below, St. John's – Flemish Cap Section, 25-27 July 1968



Source: Templeman, 1969

Figure 2.3–7 Temperature (°C) Above and Salinity (‰) Below, Section C, St. John's – Flemish Cap, 29-31 July, 1971

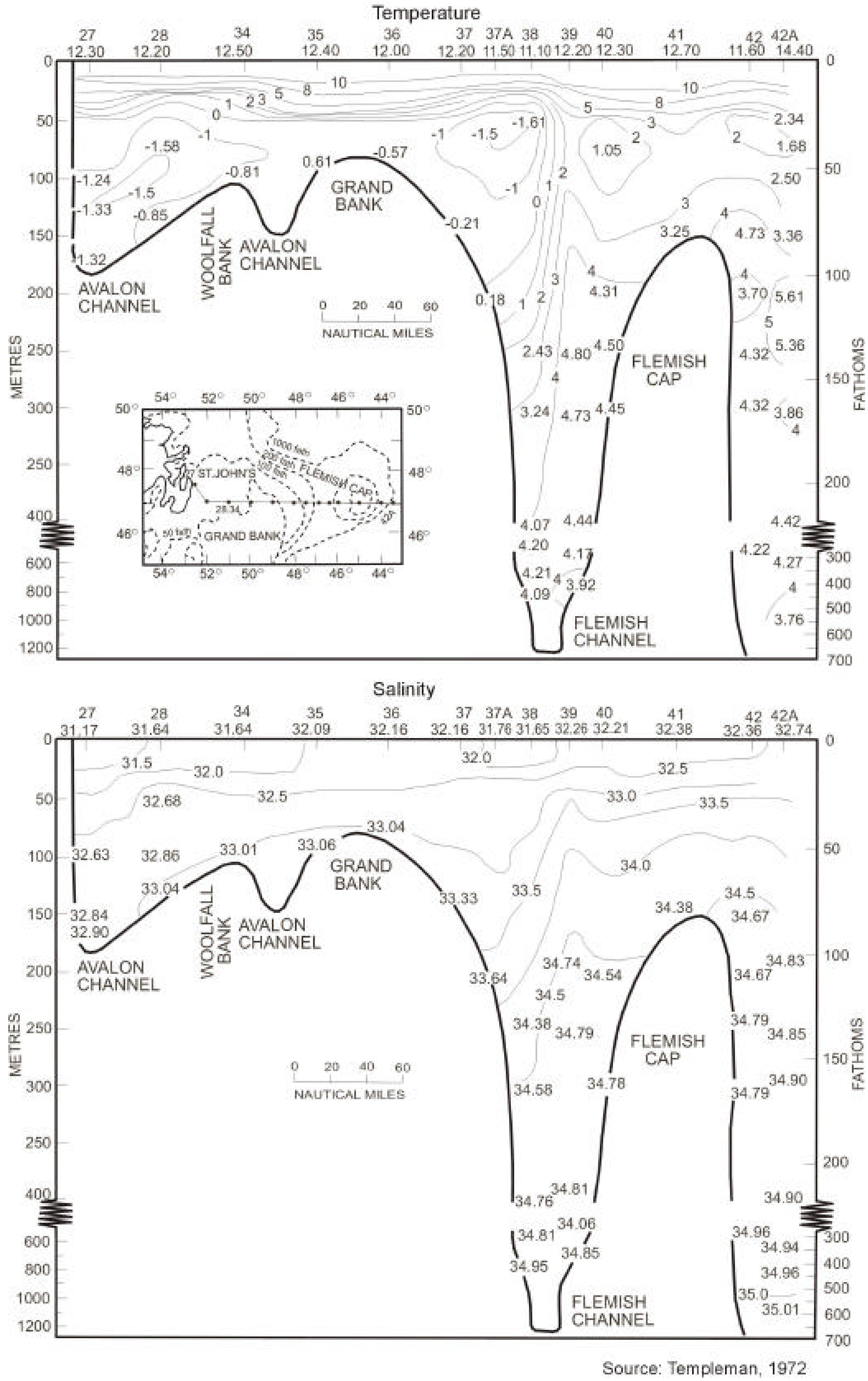
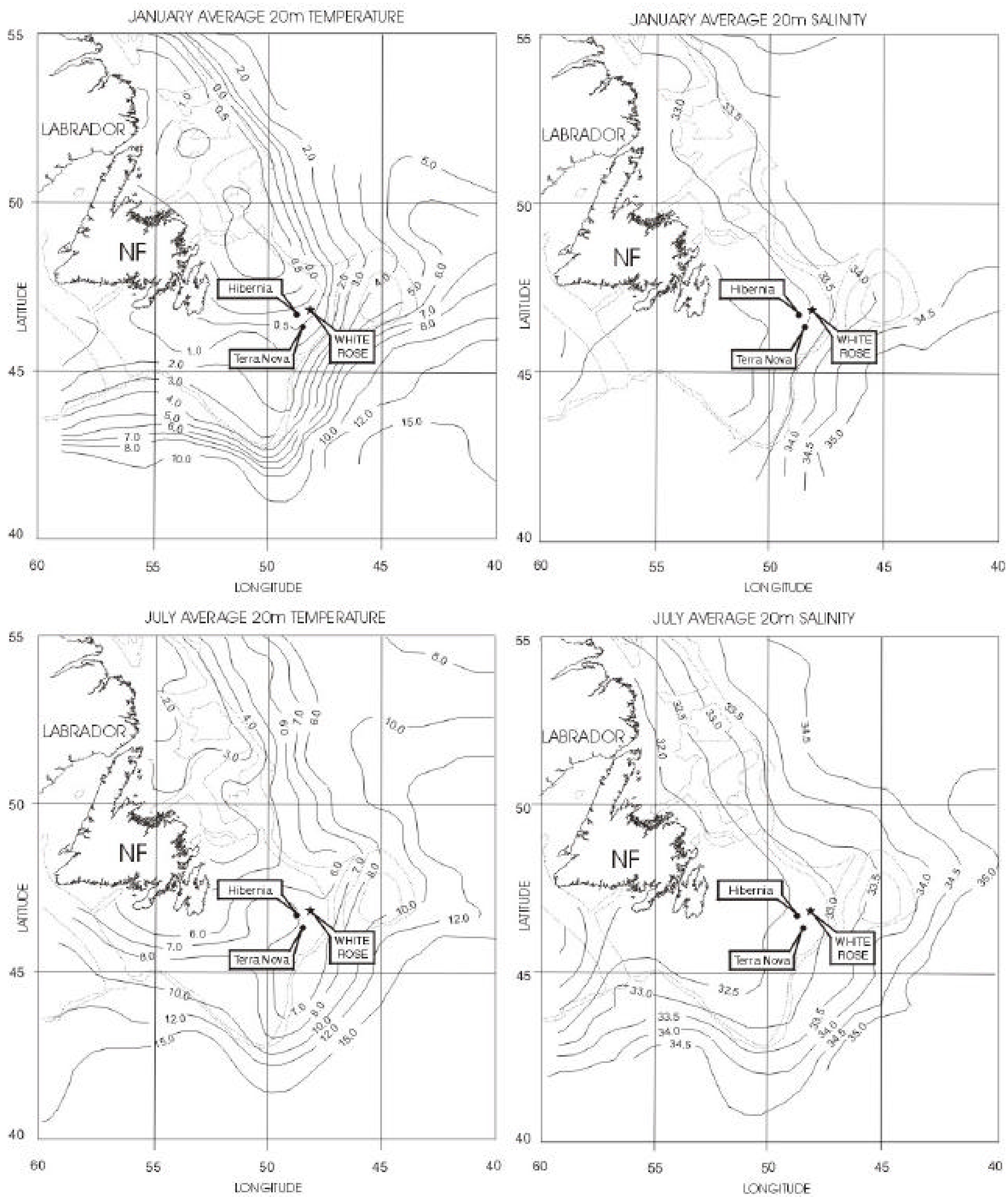


Figure 2.3–8 Average Spatial Distribution of Temperatures and Salinity at 20 m in January and July

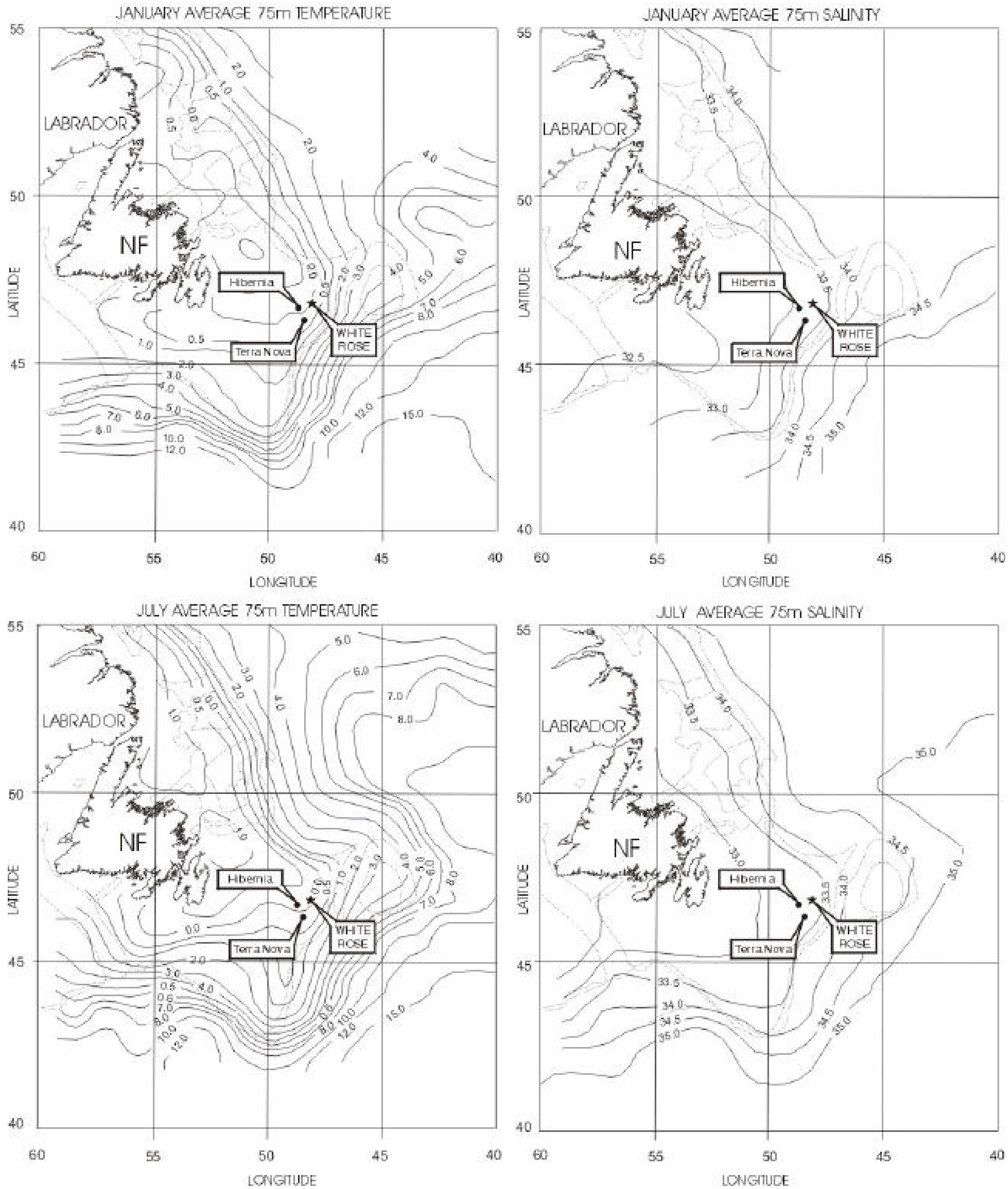
Figure 2.3-8 Average Spatial Distribution of Temperatures and Salinity at 20m in January and July



Source: Colbourne and Foote (1994)

Figure 2.3–9 Average Spatial Distribution of Temperatures and Salinity at 75 m in January and July

Figure 2.3 -9 Average Spatial Distribution of Temperatures and Salinity at 75m in January and July



Source: Colbourne and Foote (1994)

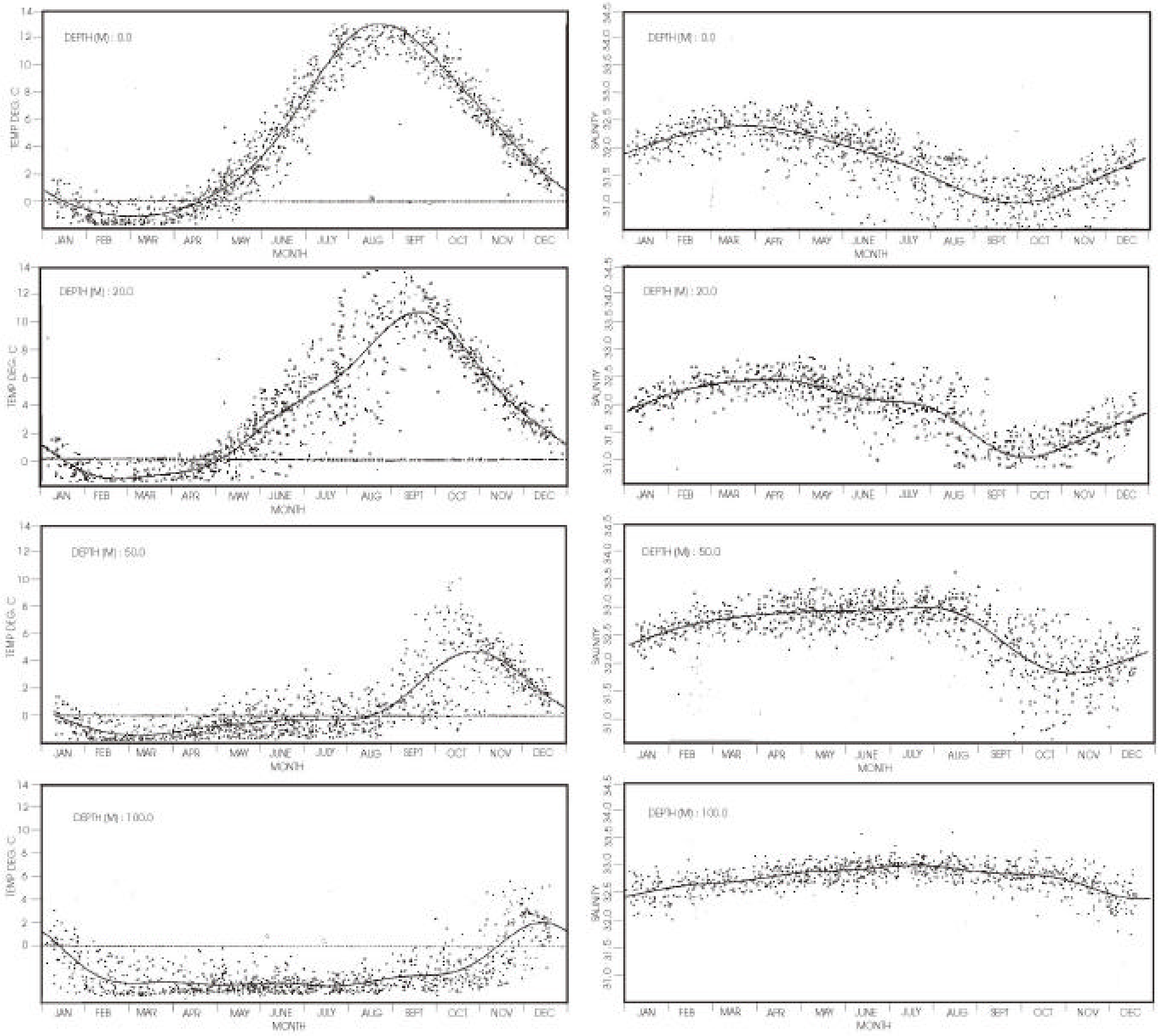
2.3.3.1 Seasonal Variations

A dominant feature of the water on the Grand Banks is a cold intermediate layer that is most apparent in summer, when spring ice melt and seasonal heating increases the stratification in the upper water and thus, inhibits heat transfer by advection. The result is a cold layer of water confined to the Continental Shelf, with temperatures ranging from –1.8 to 0.0°C between the seasonally heated upper layer and warmer slope or mixed water near the bottom (Colbourne et al. 1996). In the winter months, the intermediate layer effectively disappears as the upper waters cool to between –1.0 and 0.0°C from January to March due to winter cooling and vertical mixing. By late April or early May, warming of the surface layer begins and stratification in the surface waters start to develop and then continues through the summer months.

In 1980, the seasonal water property variations across the Grand Banks were studied by MacLaren Plansearch for Mobil Oil Canada. They measured the water properties along latitudes 44°N, 46°N and 47°N. They found that water column stratification was mainly determined by temperatures, with little change in surface salinity throughout the sampling period from April 1980 to February 1981. Stratification was weakest from January to April, with temperature in the upper 50 m between 0 and 3°C and salinities between 32 and 33 parts per thousand (expressed as I). Maximum stratification occurs from July to September, with temperatures through the water column ranging from 0 to 15°C and salinities from 32 to 33‰ (Forrester and Benoit 1981). The depth of the pycnocline was 60 m when the water column began to become stratified in May. The density gradient strengthened and decreased in depth during the summer to a depth of 30 m in August and September. The cold water core of the Labrador Current with temperature less than -1°C and salinity of 33‰ was identified along both the western and eastern edges of the Grand Banks. The core was persistent and observed throughout the sampling period.

Seasonal variations of temperature, salinity and density (sigma-t) for Station 27 located 8 km off St. John's in the Avalon Channel have been presented by Colbourne and Fitzpatrick (1994). They presented monthly means calculated from a data set for years 1946 to 1993, where the sampling was carried out on a frequent basis, some years at two to four times per month. The largest seasonal variations occurred at the surface, where maximum temperatures of greater than 12°C occurred in August and September, and minimum temperatures (<-1°C) occurred in February and March (Figure 2.3-10). The maximum salinity (>32.5‰) occurred in March and April and the minimum salinity (<31‰) occurred in September and October. The maximum density (sigma-t >26) occurred in March and April, and the minimum density (sigma-t <23.5) occurred in August and September.

Figure 2.3–10 Average Annual Temperature and Salinity at Station 27



Source: Colbourne and Fitzpatrick (1994)

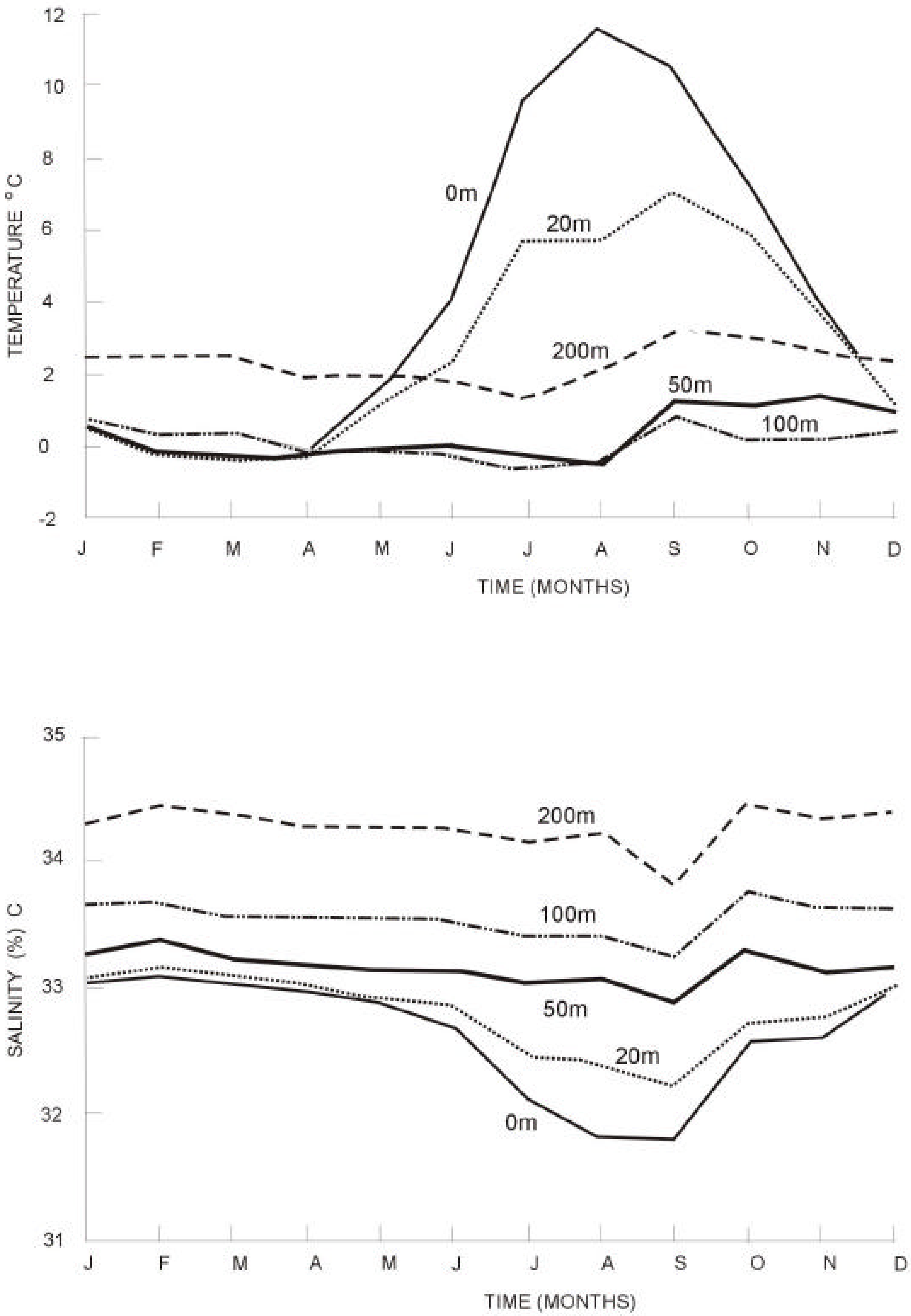
At increasing depths, the amplitude of the annual variation decreases. For temperature, the annual variation or cycle lags behind that at the surface as depth increases. The variation in the annual temperature cycle with depth can be explained as vertical mixing of heat input caused by accumulated heating at the surface during spring and summer (Petrie at al. 1990). The annual cycle in salinity and density also lags behind that at the surface with increasing depth, but Petrie et al. (1990) show that this annual cycle cannot be explained solely by air-sea exchange (precipitation and evaporation) and vertical mixing. Instead, the amplitudes and phases of the annual salinity cycle together with estimates of freshwater flux suggest that southward advection in combination with melting sea ice and coastal runoff on the Labrador Shelf, contributes significantly to the salinity component.

The seasonal variability over the northeast Grand Banks near the White Rose location has been presented by Drinkwater and Trites (1986) for bottle data collected between 1910 and 1982. The seasonal variations show a pattern where the variability is largest at the surface and decreases with depth, similar to Station 27. The least variability in both temperature and salinity is between 50 and 100 m. At the surface, the highest temperature is in August and the lowest is in March and April, while the highest salinity is in February and the lowest is in August and September (Figure 2.3-11).

For the White Rose area, the monthly temperatures and salinities at depths of 0, 20, 50 and 100 m from temperature and salinity data obtained from BIO archives for years 1960 to 2000 are shown in Tables 2.3-1 to 2.3-4, respectively. The majority of the data in the archives are for summer months. The tables show the mean, maximum, and minimum values plus the standard deviation. These data for White Rose show that at the surface the warmest temperatures are in July and August and the coldest in February. The lowest salinity is in August and the highest during the winter months. At 20 m below the surface, the highest temperature and lowest salinity is in September, and the lowest temperature and highest salinity is in February. At 50 and 100 m, the temperature and salinity variations are smaller. The temperatures are usually between –1.6 and 2°C, and salinities between 32.6 and 33.5‰.

Typical profile plots for each season, represented by February, May, August, and November are shown in Figure 2.3-12. These vertical profiles show that the water column at White Rose is a two-layer system over most of the year, except in winter, when the water column is uniformly cold. In spring, increased solar radiation heats the surface waters and, together with mixing by surface waves, it produces a well-mixed layer in the upper 10 to 15 m. Below the thermocline is well mixed colder and higher salinity water than found near the surface. In July and August, the surface temperatures are the warmest of the year. In October and November, the surface mixed layer deepens because of increased vertical mixing caused by stronger autumn winds. Together with decreased surface heating, the thermocline begins to erode, reaching winter near isothermal conditions in January.

Figure 2.3–11 The Seasonal Variations of the Monthly Mean Temperature and Salinity for the Northeastern Slope of the Grand Bank



Source: Drinkwater and Trites (1986)

Table 2.3–1 Monthly Temperature and Salinity Statistics from Historical Bottle Data in the White Rose Area (Surface, 1960 to 2000)

Temperature (°C)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	6	0.53	-0.20	1.16	0.54	0.10	0.96
Feb	9	-0.38	-1.81	0.55	0.87	-0.95	0.19
Mar	9	-0.32	-1.57	0.50	0.82	-0.86	0.22
Apr	17	0.07	-0.91	1.57	0.71	-0.27	0.41
May	18	1.74	-0.24	4.52	1.35	1.12	2.36
June	17	4.74	2.98	10.04	2.21	3.69	5.79
July	37	10.66	7.26	13.70	1.41	10.21	11.11
Aug	11	10.57	8.30	14.26	1.85	9.48	11.66
Sept	3	10.16	9.08	11.81	1.45	8.52	11.80
Oct	5	6.87	4.20	8.54	1.70	5.38	8.36
Nov	9	4.06	2.30	5.95	1.43	3.13	4.99
Dec	1	1.52	1.52	1.52	-	-	-
Salinity (‰)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	6	32.83	32.20	33.30	0.36	32.54	33.12
Feb	9	32.90	32.61	33.29	0.22	32.76	33.04
Mar	9	32.92	32.81	33.29	0.15	32.82	33.02
Apr	17	32.90	32.64	33.13	0.13	32.84	32.96
May	18	32.76	32.25	33.06	0.21	32.66	32.86
June	17	32.60	32.32	32.90	0.15	32.53	32.67
July	37	32.12	31.08	32.69	0.33	32.01	32.23
Aug	11	31.51	30.64	32.32	0.50	31.18	31.84
Sept	3	31.79	31.55	32.04	0.25	31.51	32.07
Oct	5	32.03	31.45	32.64	0.46	31.63	32.43
Nov	9	32.40	31.80	32.95	0.40	32.14	32.66
Dec	1	32.99	32.99	32.99	-	-	-

[1] N – Number of observations. Each observation was assumed to be independent for calculating the 95% confidence limits of the population mean.
[2] Mean – sample mean.
[3] Min – minimum observed value.
[4] Max – maximum observed value.
[5] STD – sample standard deviation.
[6] 95% Limits – the lower and the upper limits of the 95% confidence limits of the population mean. There is a 2.5% chance the true monthly mean will lie below the smaller value and a 2.5% chance it will lie above the larger value.

Table 2.3–2 Monthly Temperature and Salinity Statistics from Historical Bottle Data in the White Rose Area (20 m Depth, 1960 to 2000)

Temperatures (°C)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	3	0.36	-0.16	0.77	0.48	-0.18	0.90
Feb	6	-0.76	-1.75	0.30	0.83	-1.42	-0.10
Mar	5	-0.22	-1.00	0.50	0.53	-0.68	0.24
Apr	20	-0.20	-1.30	1.56	0.67	-0.49	0.09
May	17	1.62	-0.26	4.08	1.08	1.11	2.13
June	18	-3.44	-1.50	7.64	1.98	2.36	4.52
July	43	7.26	2.50	11.92	2.09	6.64	7.88
Aug	9	6.39	-0.80	12.01	4.02	3.76	9.02
Sept	3	9.01	6.49	11.82	2.68	5.98	12.04
Oct	12	7.32	3.83	8.92	1.44	6.51	8.13
Nov	7	4.24	2.03	5.96	1.49	3.14	5.34
Dec	1	1.44	1.44	1.44	-	-	-
Salinity (‰)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	3	32.83	32.20	33.30	0.36	32.72	32.94
Feb	6	32.99	32.75	33.29	0.19	32.84	33.14
Mar	5	32.89	32.81	32.98	0.07	32.83	32.95
Apr	6	32.89	32.83	32.99	0.06	32.81	32.97
May	17	32.73	32.44	33.04	0.16	32.65	32.81
June	13	32.58	32.35	32.67	0.10	32.53	32.63
July	43	32.34	31.69	32.77	0.24	32.27	32.41
Aug	9	32.26	31.43	32.95	0.46	31.96	32.56
Sept	3	31.87	31.76	32.07	0.17	31.68	32.06
Oct	12	32.00	31.61	32.32	0.18	31.90	32.10
Nov	7	32.31	31.79	32.87	0.38	32.03	32.59
Dec	1	32.99	32.99	32.99	-	-	-

[1] N – Number of observations. Each observation was assumed to be independent for calculating the 95% confidence limits of the population mean.

[2] Mean – sample mean.

[3] Min – minimum observed value.

[4] Max – maximum observed value.

[5] STD – sample standard deviation.

[6] 95% Limits – the lower and the upper limits of the 95% confidence limits of the population mean. There is a 2.5% chance the true monthly mean will lie below the smaller value and a 2.5% chance it will lie above the larger value.

Table 2.3–3 Monthly Temperatures and Salinity Statistics from Historical Bottle Data in the White Rose Area (50 m Depth, 1960 to 2000)

Temperature (°C)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	4	0.07	-0.17	0.59	0.35	-0.27	0.41
Feb	7	-0.68	-1.75	0.26	0.80	-1.27	-0.09
Mar	6	-0.30	-1.10	0.30	0.45	-0.66	0.06
Apr	31	-0.67	-1.67	0.47	0.55	-0.86	-0.48
May	18	-0.06	-1.69	1.13	0.76	-0.41	0.29
June	15	0.26	-1.44	1.39	0.78	-0.31	0.65
July	46	-0.53	-1.48	1.47	0.71	-0.74	-0.32
Aug	10	-0.96	-1.70	0.33	0.86	-1.49	-0.43
Sept	3	-1.07	-1.40	-0.88	0.28	-1.39	-0.75
Oct	9	-0.17	-1.37	1.93	1.27	-1.00	0.66
Nov	8	1.52	-0.70	5.24	1.82	0.26	2.78
Dec	1	1.26	1.26	1.26	-	-	-
Salinity (‰)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	4	32.95	32.80	33.06	0.11	32.84	33.06
Feb	7	33.08	32.79	33.29	0.17	32.95	33.21
Mar	6	32.89	32.83	32.99	0.06	32.84	32.94
Apr	31	32.79	32.51	33.15	0.21	32.72	32.86
May	18	32.88	32.50	33.14	0.16	32.81	32.95
June	15	32.85	32.64	33.16	0.16	32.77	32.93
July	46	32.91	32.74	33.18	0.11	32.88	32.94
Aug	10	32.89	32.65	33.11	0.17	32.78	33.00
Sept	3	32.83	32.60	32.96	0.20	32.60	33.06
Oct	9	32.80	32.67	33.11	0.14	32.71	32.89
Nov	8	32.95	32.10	33.80	0.52	32.59	33.31
Dec	1	33.42	33.42	33.42	-	-	-

[1] N – Number of observations. Each observation was assumed to be independent for calculating the 95% confidence limits of the population mean.

[2] Mean – sample mean.

[3] Min – minimum observed value.

[4] Max – maximum observed value.

[5] STD – sample standard deviation.

[6] 95% Limits – the lower and the upper limits of the 95% confidence limits of the population mean. There is a 2.5% chance the true monthly mean will lie below the smaller value and a 2.5% chance it will lie above the larger value.

Table 2.3–4 Monthly Temperature and Salinity Statistics from Historical Bottle Data in the White Rose Area (100 m Depth, 1960 to 2000)

Temperature (°C)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	4	-0.28	-0.47	0.14	0.28	-0.55	-0.01
Feb	7	-0.46	-1.64	0.31	0.70	-0.98	0.06
Mar	6	0.01	-0.55	0.30	0.34	-0.26	0.28
Apr	14	-0.55	-1.60	0.18	0.50	-0.81	-0.29
May	19	-0.63	-1.72	0.34	0.69	-0.94	-0.32
June	11	-0.57	-1.33	0.30	0.58	-0.91	-0.23
July	43	-0.69	-1.64	1.57	0.87	-0.95	-0.43
Aug	6	-0.74	-1.70	1.64	1.28	-1.76	0.28
Sept	3	-1.15	-1.35	-0.93	0.21	-1.39	-0.91
Oct	5	-0.84	-1.25	-0.34	0.37	-1.16	-0.52
Nov	9	-0.51	-1.48	1.10	0.89	-1.09	0.07
Dec	1	-0.76	-0.76	-0.76	-	-	-
Salinity (‰)							
Mon	**N[1]**	**Mean[2]**	**Min[3]**	**Max[4]**	**STD[5]**	**95% Limits[6]**	
Jan	4	33.46	33.30	33.64	0.16	33.30	33.62
Feb	7	33.30	33.01	33.59	0.22	33.14	33.46
Mar	6	33.34	33.19	33.44	0.09	33.27	33.41
Apr	14	33.28	32.92	33.51	0.17	33.19	33.37
May	19	33.28	33.02	33.56	0.19	33.19	33.37
Jun	11	33.31	32.94	33.51	0.16	33.22	33.40
July	43	33.23	33.08	33.46	0.10	33.20	33.26
Aug	6	33.26	33.11	33.37	0.11	33.17	33.35
Sept	3	33.33	33.24	33.50	0.15	33.16	33.50
Oct	5	33.21	33.06	33.49	0.17	33.06	33.36
Nov	9	33.40	33.05	33.90	0.30	33.20	33.60
Dec	1	33.42	33.42	33.42	-	-	-

[1] N – Number of observations. Each observation was assumed to be independent for calculating the 95% confidence limits of the population mean.

[2] Mean – sample mean.

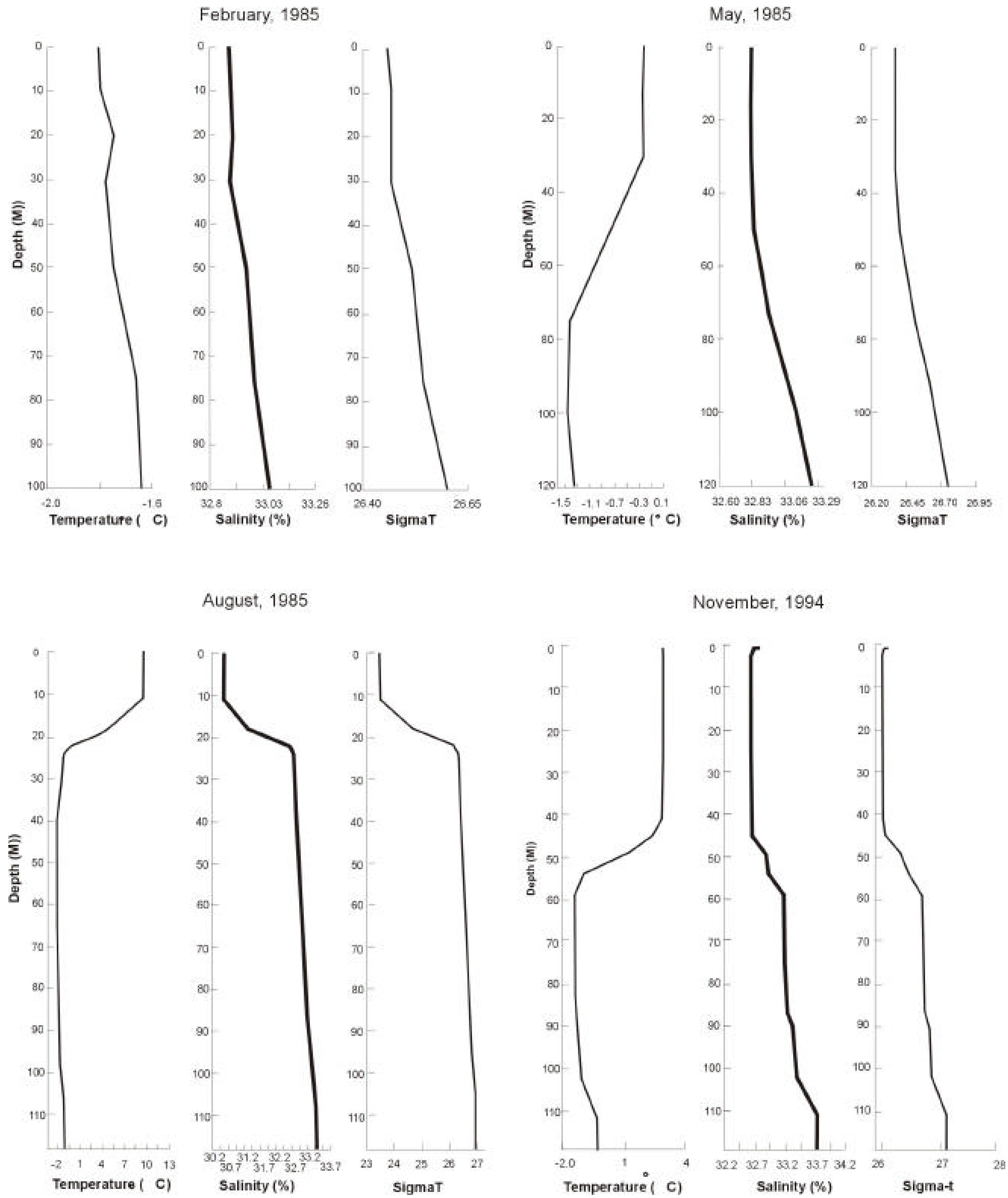
[3] Min – minimum observed value.

[4] Max – maximum observed value.

[5] STD – sample standard deviation.

[6] 95% Limits – the lower and the upper limits of the 95% confidence limits of the population mean. There is a 2.5% chance the true monthly mean will lie below the smaller value and a 2.5% chance it will lie above the larger value.

Figure 2.3–12 Seasonal Depth Profile of Temperature, Salinity and Sigma-t at White Rose



2.3.4 Ocean Currents

The general circulation and mean currents on the Grand Banks are well understood from geostrophic calculations, drifter data, current modelling, and direct measurements. The variabilites are less understood because the quantity of direct observations remains limited.

2.3.4.1 Geostrophic Flow

Geostrophic calculations are an indirect means of deriving the velocity field from the internal pressure and density distribution of the water. The internal pressure and density distributions are determined from vertical profiles of temperature and salinity. This method was widely used by oceanographers to understand the general pattern of ocean currents before current meters became available. In the 1950s and 1960s, the IIP did routine surveys on the outer edge of the Grand Banks to assist with understanding iceberg drift. In later years, they relied more heavily on surface drifters. The dynamic topography of the sea surface calculated from temperature and salinity measurements collected between May 23 and June 4, 1951, is shown in Figure 2.3-13. This figure shows general features of the current pattern in the study area. The Labrador Current is flowing southward with a maximum geostrophic component of approximately 60 cm/sec east of White Rose on the West Side of Flemish Pass at location 47° 15′W (Soule et al. 1951). Other interesting features include a clockwise circulation around Flemish Cap, an eastward flowing current in the vicinity of White Rose, and the influence of the North Atlantic Current as far north as 46°N in the area south of Flemish Cap. South of White Rose, the core of the North Atlantic current is at 45°N during this particular year. The north boundary of the North Atlantic Current is quite variable, but often seen further south and at times further north.

Recent geostrophic currents were calculated by Colbourne (2000) from the temperature and salinity measurements taken along the standard Flemish cap transit during summers in 1998 and 1999 (Figure 2.3-14). The geostrophic currents shown in the figure are the components perpendicular to the Flemish Cap transit. Colbourne (2000) found that during 1999 the offshore branch of the Labrador Current was narrower than usual (less than 100 km) and had higher current speeds than in 1998. In 1999, the southward component of the surface currents at the time of sampling was greater than approximately 0.7 km/h (0.45 mph). At the location of White Rose, the geostrophic currents were negligible.

Figure 2.3–13 Dynamic Topography of the Sea Surface Relative to the 1,000 Decibar Surface from Data Collected 23 May to June 1951

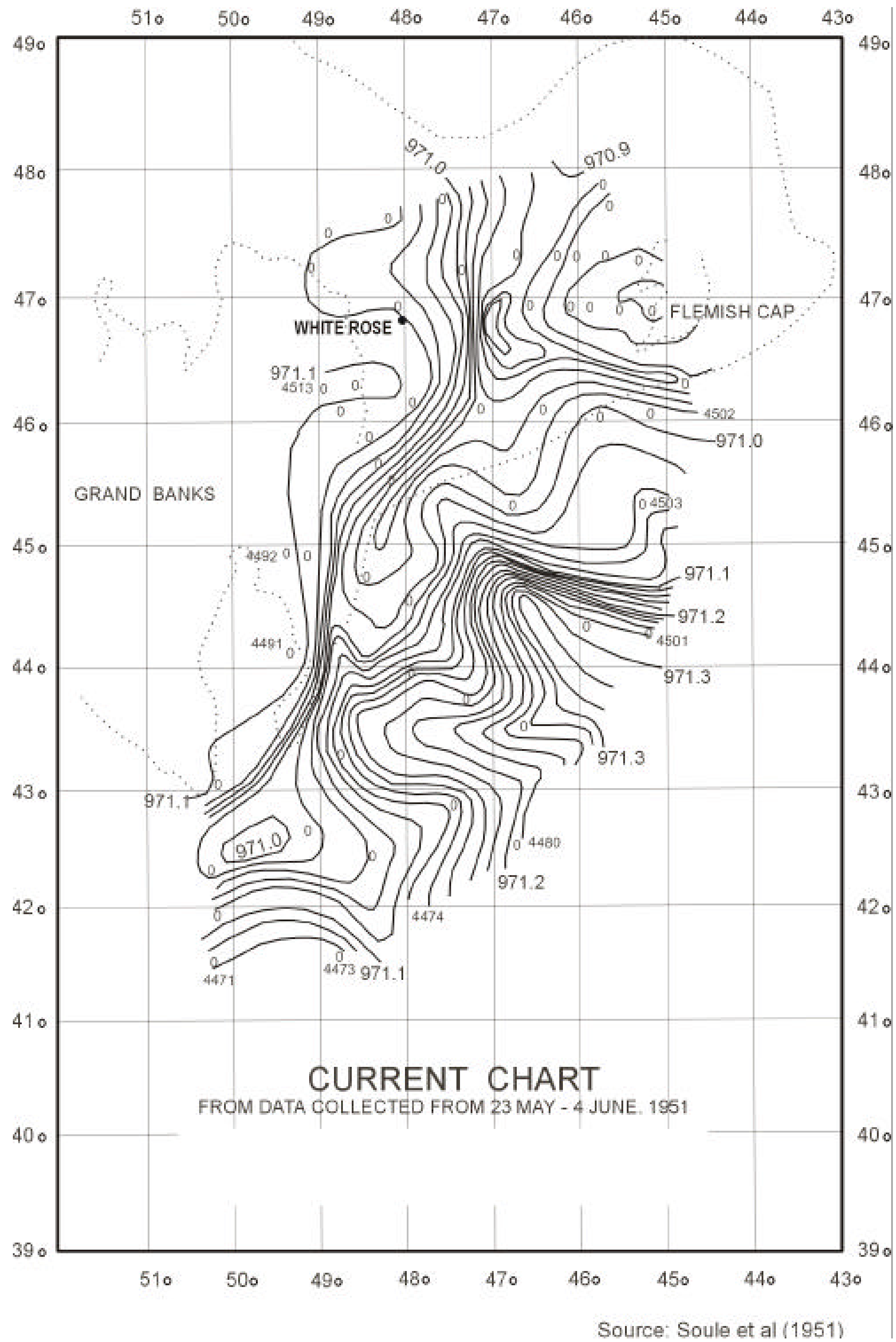
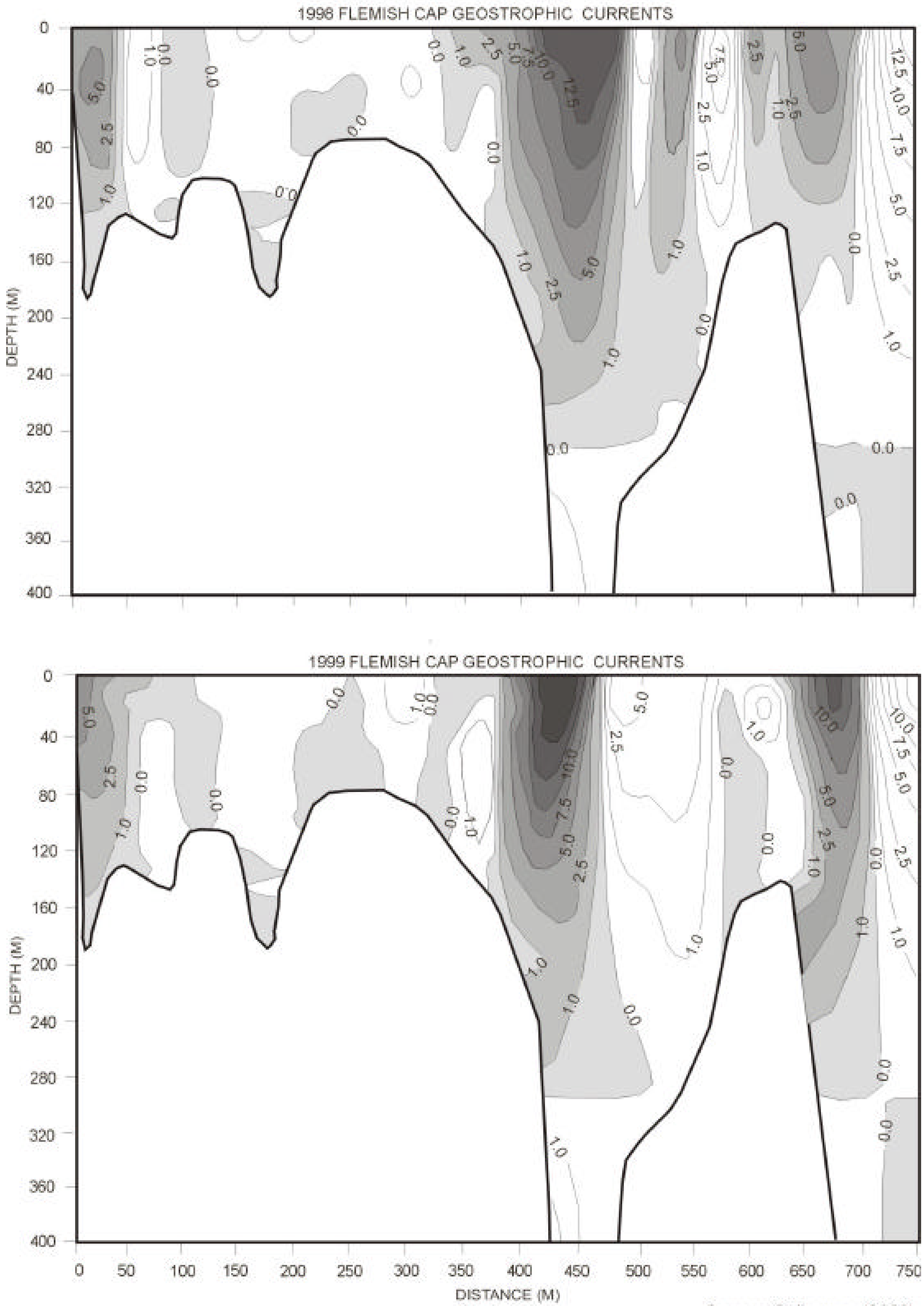


Figure 2.3–14 A Vertical Cross-Section of the Geostrophic Currents (cm/s) Along the Standard Flemish Cap Transect for the Summer of 1998 and 1999. Negative Southward Values are shaded



Source: Colbourne (2000)

2.3.4.2 Surface Circulation from Drifter Buoys

During the last 25 years, satellite-tracked drifting buoys have been deployed in the Labrador Current to measure Lagrangian surface currents. The IIP has been operating a drifting buoy program since 1976 during the spring iceberg season. Additional surface drifters have been deployed by BIO (Petrie and Isenor 1984; Petrie and Warnell 1988), and by the Northwest Atlantic Research Centre in support of northern cod research (Pepin and Helbig 1997). A composite of 144 drifter tracks was compiled by Helbig and Brett (1995). The drifter track positions and their calculated mean velocity vectors are shown in Figure 2.3-15. Surface currents derived by Murphy et al. (1991) and updated by Yao et al. (1992) are presented in Figure 2.3-16. These surface currents were derived from the IIP's drifting buoy data between 1976 and 1989 (Murphy et al. 1991) and updated by Yao et al. (1992) using two more years of drifter data and some current meter data.

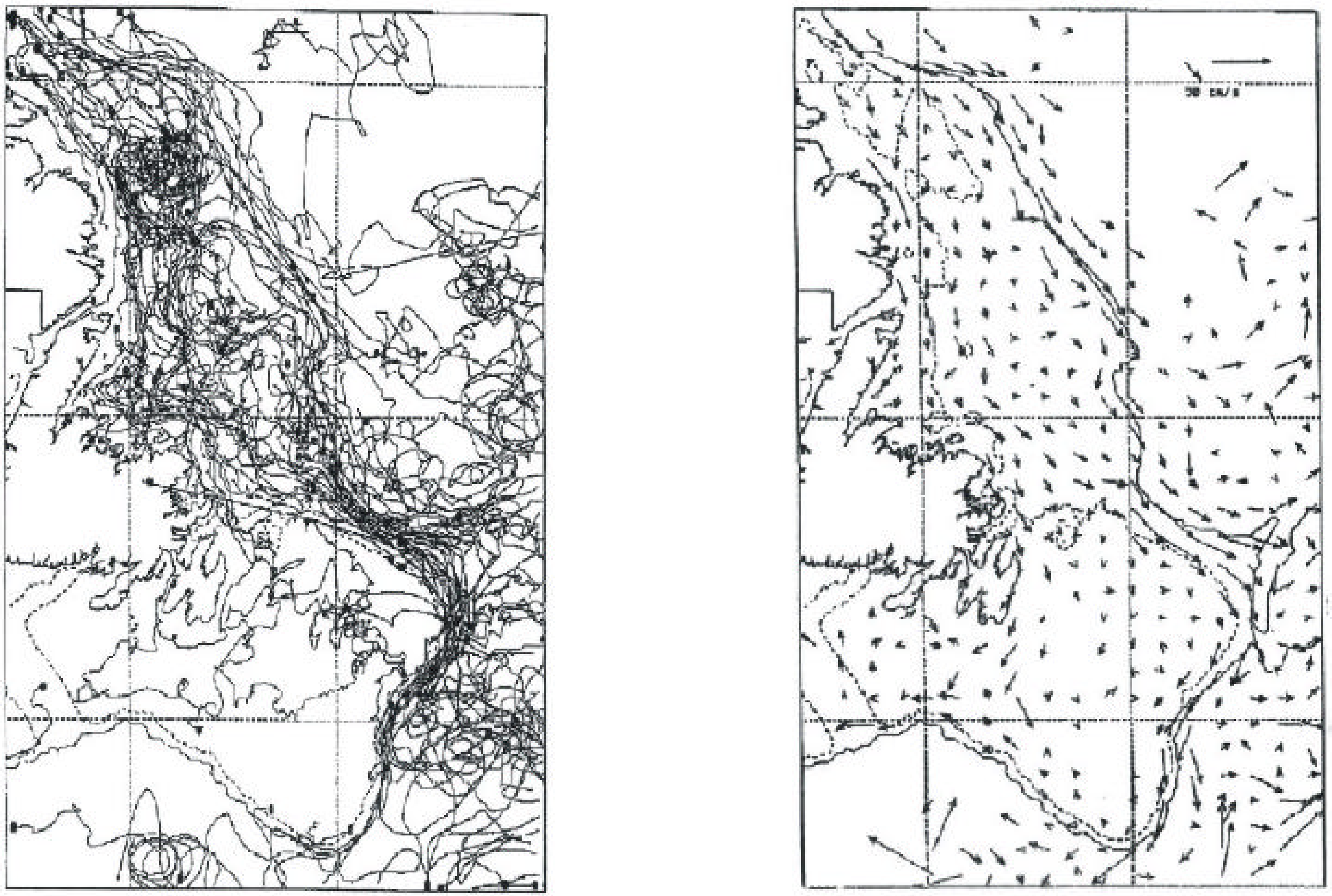
The IIP's near-surface current map was compared with some moored current measurements made between 1980 and 1993 (Narayanan et al. 1996). Narayanan et al. (1996) found that the measurements were generally consistent with the IIP gridded surface current field, except that the currents were considered to be overestimated in some locations. This data set is periodically revised, as new observations become available, and is still the best source of surface current data available for the Grand Banks and surrounding regions.

2.3.4.3 Numerical Models

The results of numerical models have also contributed to the knowledge of the circulation on the Grand Banks. The numerical model developed by Greenberg and Petrie (1988) produced a detailed, high-resolution presentation of the barotrophic (vertically, uniform currents) mean circulation on the Grand Banks and surrounding areas. The 1988 model was a first step in modelling the mean circulation in the Newfoundland Shelf region and did not take into account the effects of stratification in the water column and the effects of wind stress, both important driving forces on the Newfoundland Shelf. The barotrophic model was driven by a sea surface slope at a northern boundary across Hamilton Bank and adjusted to give a specified inflow over different parts of the shelf and/or the shelf edge. A map of the currents on the Newfoundland Shelf, as calculated from the Greenberg and Petrie model is presented in Figure 2.3-17. The major characteristics of the circulation produced by their model, were: 1) a strong topographical steering of the currents; 2) the splitting of the Labrador Current into two branches north of Flemish Pass; and 3) northwestward movement of water over the eastern part of the Grand Banks.

Narayanan et al. (1996) compared the current meter data sets obtained between 1980 and 1993 with the barotrophic model results of Greenberg and Petrie (1988), and found that the model predictions were more or less in agreement with observations made at the comparison mooring sites. The model underestimated the magnitude of the offshore branch of the Labrador Current along the northeast.

Figure 2.3–15 Computed Currents from Drifting Buoy Data

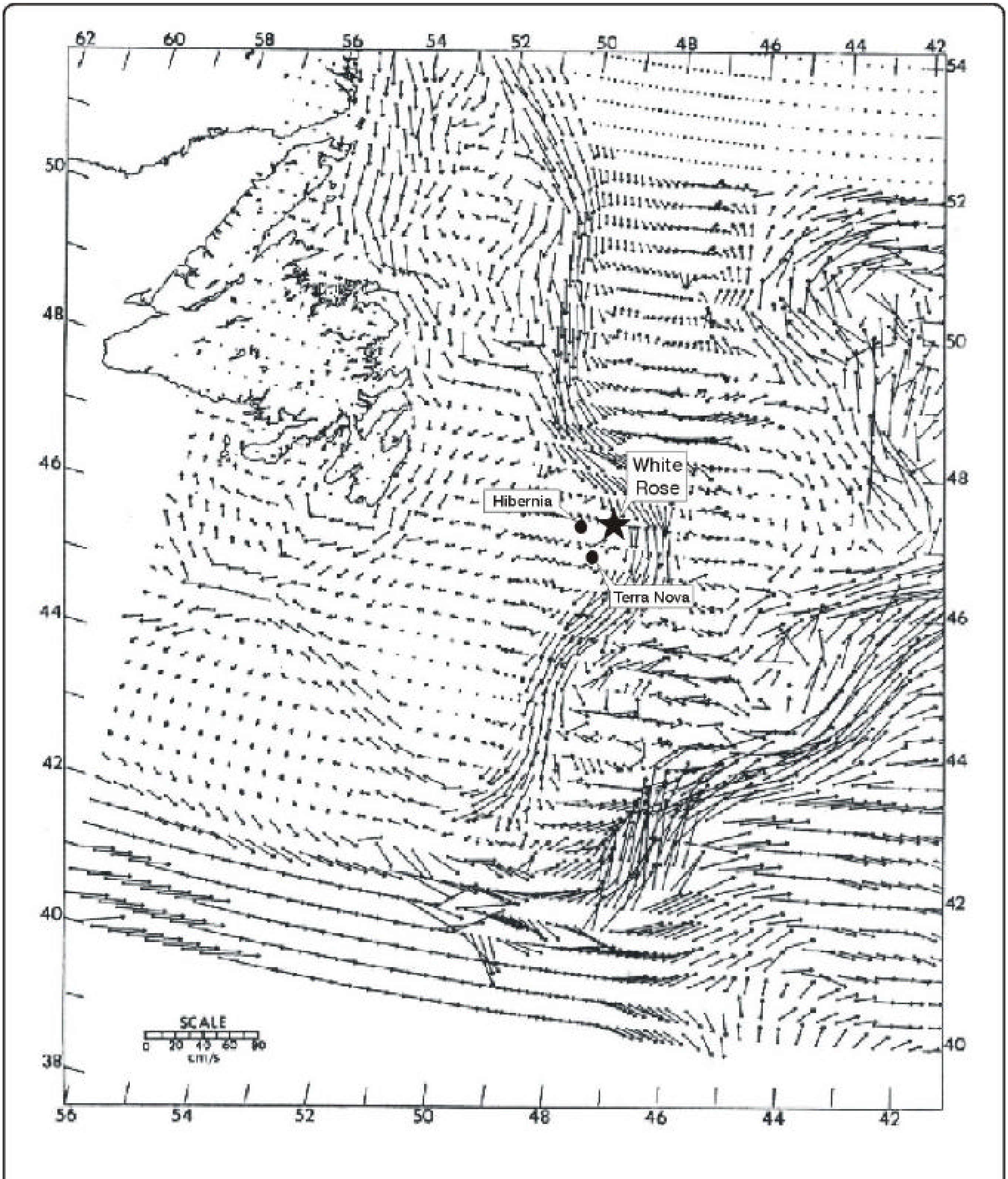


Data: From the late 1970's to 1994

Mean Velocity Vectors

1401-75.CDR 14JUL00

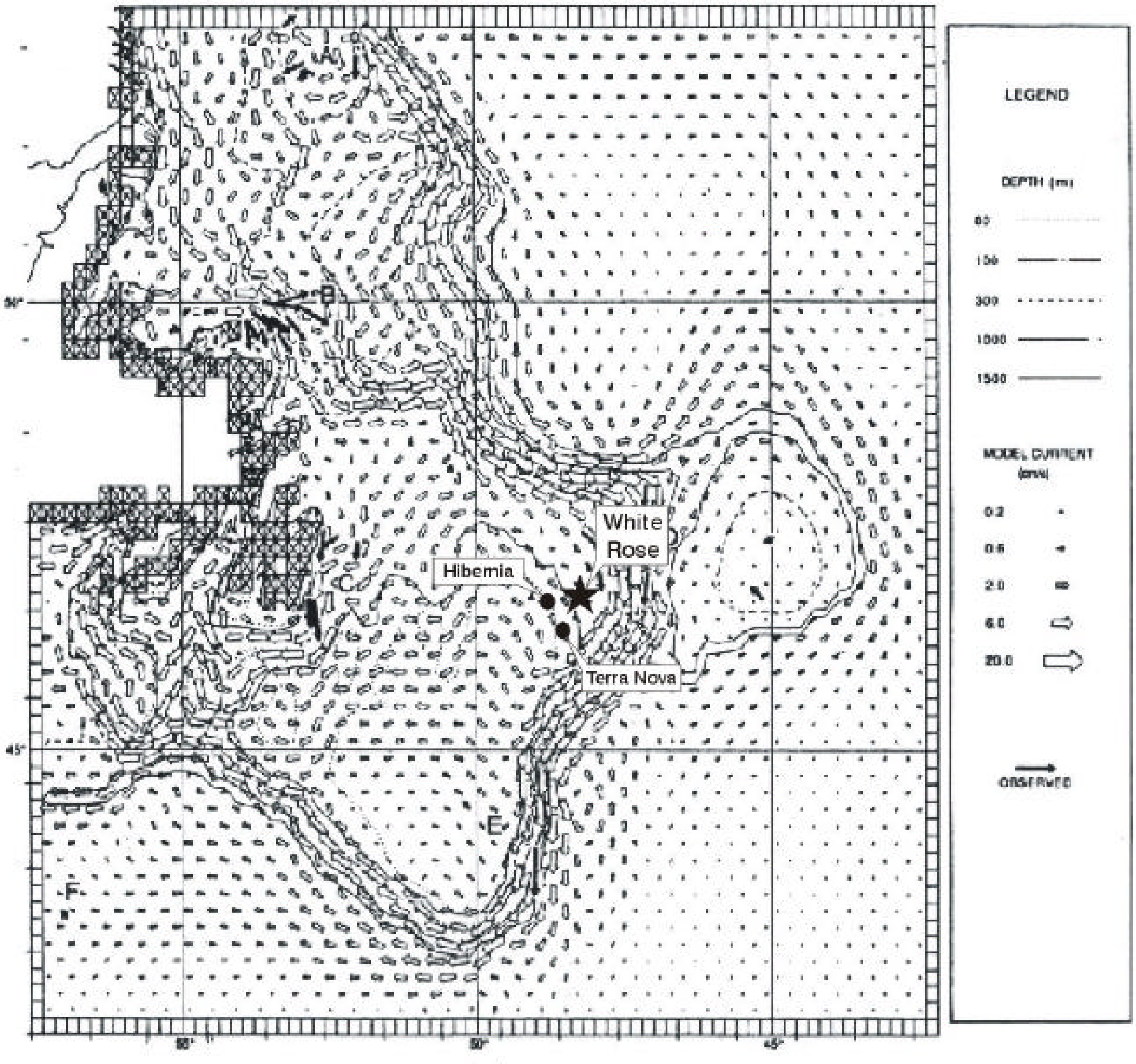
Figure 2.3–16 Composite Map of Mean Near-Surface Currents



1401-78.cdr 26JUL00

Source: Murphy et al. (1991); Yao et al. (1992)

Figure 2.3–17 Model-Derived Depth-Averaged Currents



1401-76.cdr 26JUL00

Source: Greenburg and Petrie (1998)

Newfoundland Shelf. It did not duplicate the clockwise circulation on Flemish Cap as indicated by drifter data (Ross 1980) or the eddylike features in the slope region south of Flemish Pass. The intersection between the Labrador Current and the North Atlantic Current was not taken into consideration in the model. Since the development of the 1988 barotrophic model, modelling of currents on the Grand Banks has been an on-going process by BIO. Two models are currently in use and can be operated in near-real time. One of the models is maintained by the Coastal Oceanography Group and the other primarily for use in predicting ice movements in the winter and spring is maintained by Dr. Tang of the Oceans Sciences Division.

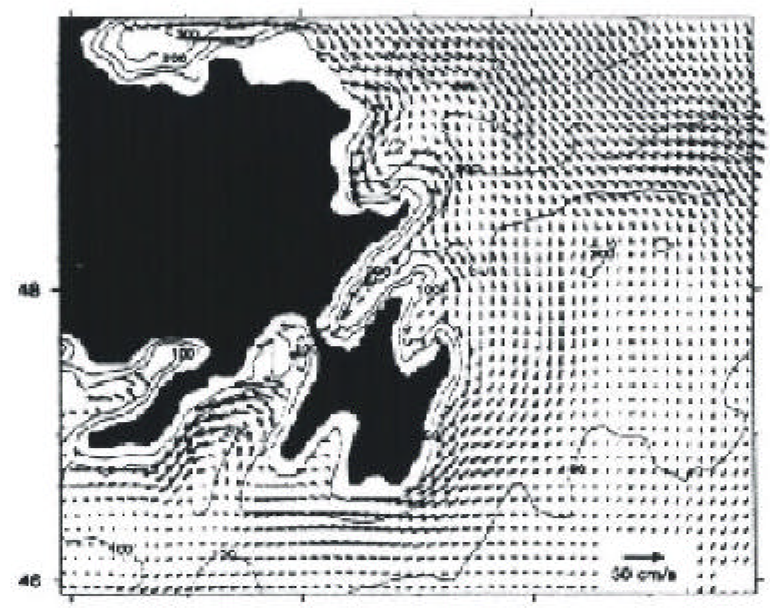
Hukuda et al. (1989) developed a three-dimensional model to estimate the mass exchange at different depths. Similar to the Greenberg and Petrie model (1988), their model was driven by specifying the sea level along a northern boundary. Similarly, their model reproduced the circulation pattern found by Greenberg and Petrie (1988). They examined the onshore-offshore mass exchange over the southeastern edge of the Grand Banks and found that the southward flowing Labrador Current along the shelf break leads to an onshore flux in the upper part of the water column and an offshore flux in the bottom Ekman layer.

Sheng and Thompson (1995) developed a model by using currents calculated from vertical density profiles across the northern boundary as input to their model. The currents, initially computed from vertical density profiles relative to fixed depth levels, were compared with observations. From the comparisons, optimal inflow boundary conditions were estimated, and used to drive the northern boundary of a limited area numerical model. This model agreed well with the Greenberg and Petrie (1988) model results and gave a high-resolution presentation of the strong topographically influenced flows of the inner and outer branches of the Labrador Current, and the anticyclonic (clockwise) gyre centred on the Flemish Cap (Figure 2.3-18).

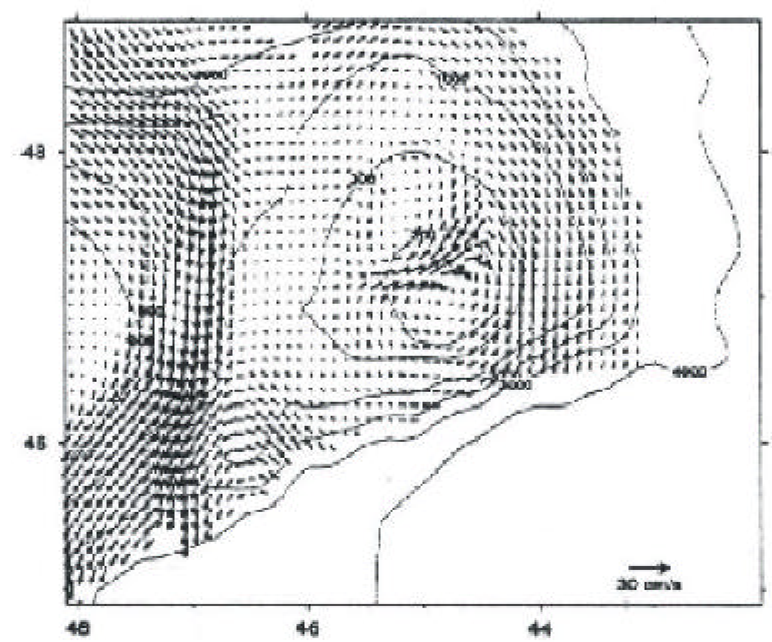
2.3.4.4 Moored Current Meter Data

In the White Rose area, 27 sets of moored current meter data have been collected in support of offshore drilling operations. Each data set has a duration of several weeks or more. These moored current meter data sets are summarized in Table 2.3-5.

Figure 2.3–18 Model-Derived Summer Currents



Inner Portion of the Grand Banks



Flemish Cap Area

1401-77.cdr 14JUL00

Source: from Sheng and Thompson (1995)

Table 2.3–5 Summary of Moored Current Meter Data Sets Available for White Rose and the Immediate Vicinity

Period	Near Surface		Mid-Depth		Near Bottom		Total Data Sets
	No of Sites	No of Data Sets	No of Sites	No of Data Sets	No of Sites	No of Data Sets	
White Rose Jul 84-Aug 88	4	4	4	6	3	4	14
Trave E-87 Feb 83–Jan 84	2	2	2	2	2	2	6
White Rose Mar 99–Oct 99	3	3	2	2	1	1	6

The maximum speed and mean velocity for each of the data sets are presented in Tables 2.3-6 to 2.3-8. The maximum speeds by month and the number of data sets in each month are shown in Table 2.3-9. The maximum speed of 89.9 cm/sec occurred during September 1999 at 20 m at White Rose N-30 (Table 2.3-6). This was not an isolated incident because a surface current of 82 cm/sec also occurred in September 1984 at White Rose N-22 (Table 2.3-6). At mid-depth, the maximum current speed in the data sets occurred in December 1983 at Trave E-87 with a speed of 46.0 cm/sec, and at White Rose in November with a speed of 43.7 cm/sec (Table 2.3-7). Near bottom the maximum current occurred in November 1985 at White Rose J-49 with a speed of 50.6 cm/sec (Table 2.3-8).

Table 2.3–6 Near Surface Currents at White Rose

Well Site	Period	Max. Speed (cm/sec)	Mean Velocity (cm/sec)	Direction
White Rose N-30	Aug – Oct, 1999	89.9	5.0	Southeast
White Rose A-17	Jun – Aug, 1999	42.1	8.4	Northeast
White Rose L-08	Mar – Jun, 1999	45.7	2.7	Northwest
White Rose E-09	May – July, 1988	45.2	7.5	Southeast
White Rose J-49	Aug – Nov, 1985	61.7	4.9	South
White Rose L-61	Dec – Feb, 1985	36.0	6.4	Northeast
White Rose N-22	Jul – Oct, 1984	82.0	19.0	Southwest
Trave E-87	Nov – Jan, 1984	55.0	8.1	South
Trave E-87	Feb – Mar, 1984	40.0	11.1	Southeast

Table 2.3–7 Currents at Mid-Depth at White Rose

Well Site	Period	Max. Speed (cm/sec)	Mean Velocity (cm/sec)	Direction
White Rose N-30	Aug – Oct, 1999	40.8	10.6	Northeast
White Rose L-08	Mar – Jun, 1999	29.4	3.8	South
White Rose A-90	Jul – Aug, 1988	24.7	3.4	Southeast
White Rose E-09	May - July, 1988	39.0	5.9	Southeast
White Rose E-09	Jan – Feb 1988	35.0	3.5	Southeast
Whites Rose E-09	Sept – Oct, 1987	32.6	9.0	Southwest
White Rose J-49	Aug – Nov, 1985	43.7	2.6	Southeast
White Rose N-22	Jul – Nov, 1984	31.0	1.8	Southeast
Trave E-87	Feb – Mar, 1983	31.0	7.5	South
Trave E-87	Nov – Jan, 1983	46.0	5.0	Southeast

Table 2.3–8 Currents Near-Bottom at White Rose

Well Site	Period	Max. Speed (cm/sec)	Mean Velocity (cm/sec)	Direction
White Rose L-08	Mar – Jun, 1999	27.6	2.8	Southeast
White Rose A-90	Jul – Aug, 1988	25.2	2.3	Southeast
White Rose E-09	May- Jul, 1988	32.6	3.7	Southwest
White Rose E-09	Jan – Feb, 1988	34.5	3.7	Southeast
White Rose E-09	Sept – Nov, 1987	36.2	3.7	Southeast
White Rose J-49	Aug – Nov, 1985	50.6	2.0	Southeast
Trave E-87	Nov – Jan, 1983	39.0	6.6	Southeast
Trave E-87	Feb – Mar, 1983	32.0	5.9	Southeast

Table 2.3–9 Maximum Current Speeds for Each Month

Month	Near Surface Currents (cm/sec)	Mid-Depth Currents (cm/sec)	Near Bottom Currents (cm/sec)
January	36.0 (2)	33.0 (2)	35.0 (2)
February	38.0 (2)	35.0 (2)	34.5 (2)
March	40.0 (1)	26.0 (1)	29.0 (1)
April	40.3 (1)	29.4 (1)	25.8 (1)
May	45.7 (2)	31.9 (1)	24.2 (1)
June	45.2 (2)	39.0 (2)	32.6 (1)
July	43.0 (3)	26.8 (3)	25.2 (3)
August	52.0 (3)	27.8 (3)	26.2 (3)
September	89.9 (3)	40.8 (4)	29.4 (3)
October	64.0 (2)	32.6 (4)	36.2 (3)
November	61.7 (2)	43.7 (3)	50.6 (3)
December	47.0 (2)	46.0 (1)	39.0 (1)
Note: The number in parenthesis is the number of data months.			

The maximum mean current velocity (residual current) over the duration of a data set occurred in the surface waters at White Rose N-22 with a speed of 19.0 cm/sec towards the southwest, as shown in Table 2.3-6. The data show that the surface current is flowing in a southeast or southerly direction more often than in other directions (Table 2.3-10). At mid-depth, the mean current velocity was towards the southeast more often than in any other direction. The maximum mean current velocity at mid-depth occurred at White Rose N-30, with a speed of 10.6 cm/sec (Table 2.3-7) towards the northeast. The bottom currents had a maximum velocity of 3.7 cm/sec (Table 2.3-9) at White Rose E-09 towards the southwest during summer and towards the southeast during winter.

Table 2.3–10 Predominant Current Directions for Each Month From the Data Sets

Month	Near Surface Currents (cm/sec)	Mid-Depth Currents (cm/sec)	Near Bottom Currents (cm/sec)
January	Northeast (1985) Southeast (1983)	South (1988) Southeast (1983)	Southeast (1988) Southeast (1983)
February	Northeast (1985) Southeast (1984)	Southeast (1988) South(1983)	Southeast (1988) Southeast (1983)
March	Southeast (1984)	South (1983)	Southeast (1983)
April	Northwest(1999)	South (1999)	Southeast (1999)
May	Northwest(1999) Southeast (1988)	South (1999)	Southeast (1999)
June	Southwest (1999) Southeast(1988)	South (1999) Southeast (1988)	Southeast (1999)
July	Northeast (1999) Southeast (1988) Southwest(1984)	Southeast (1988) Southeast(1988) Southeast (1984)	Southwest (1988) Southeast (1988)
August	Southeast (1999) South (1985) Southwest(1984)	Northeast (1999) South (1988) Southeast (1984)	Southeast (1985) Southwest (1988)
September	Southeast (1999) South (1985) Southwest(1984)	Northeast (1999) West (1987) Southeast (1985) Southeast (1984)	Southeast (1985) Southeast (1987)
October	South (1985) Southwest (1984)	Northeast (1999) Southwest(1987) Southeast (1985) Southeast (1984)	Southeast (1985)
November	South (1985) South (1983)	Southeast (1985) Southeast(1984) Southeast (1983)	Southeast (1987) Southeast (1985)
December	Northeast (1985) South (1983)	Southeast (1983)	Southeast (1987)

Progressive vector diagrams in Figures 2.3-19 to 2.3-21 presents the distance and direction a molecule of water would travel if the flow were spatially uniform. Variabilities in the flow are evident in the diagrams. The diagrams are presented by depth for each season. Since the quantity of data is limited for each season, the plots may not be representative of measured currents at other times or in the future.

Figure 2.3–19 Progressive Vector Diagrams of Near Surface Currents at White Rose

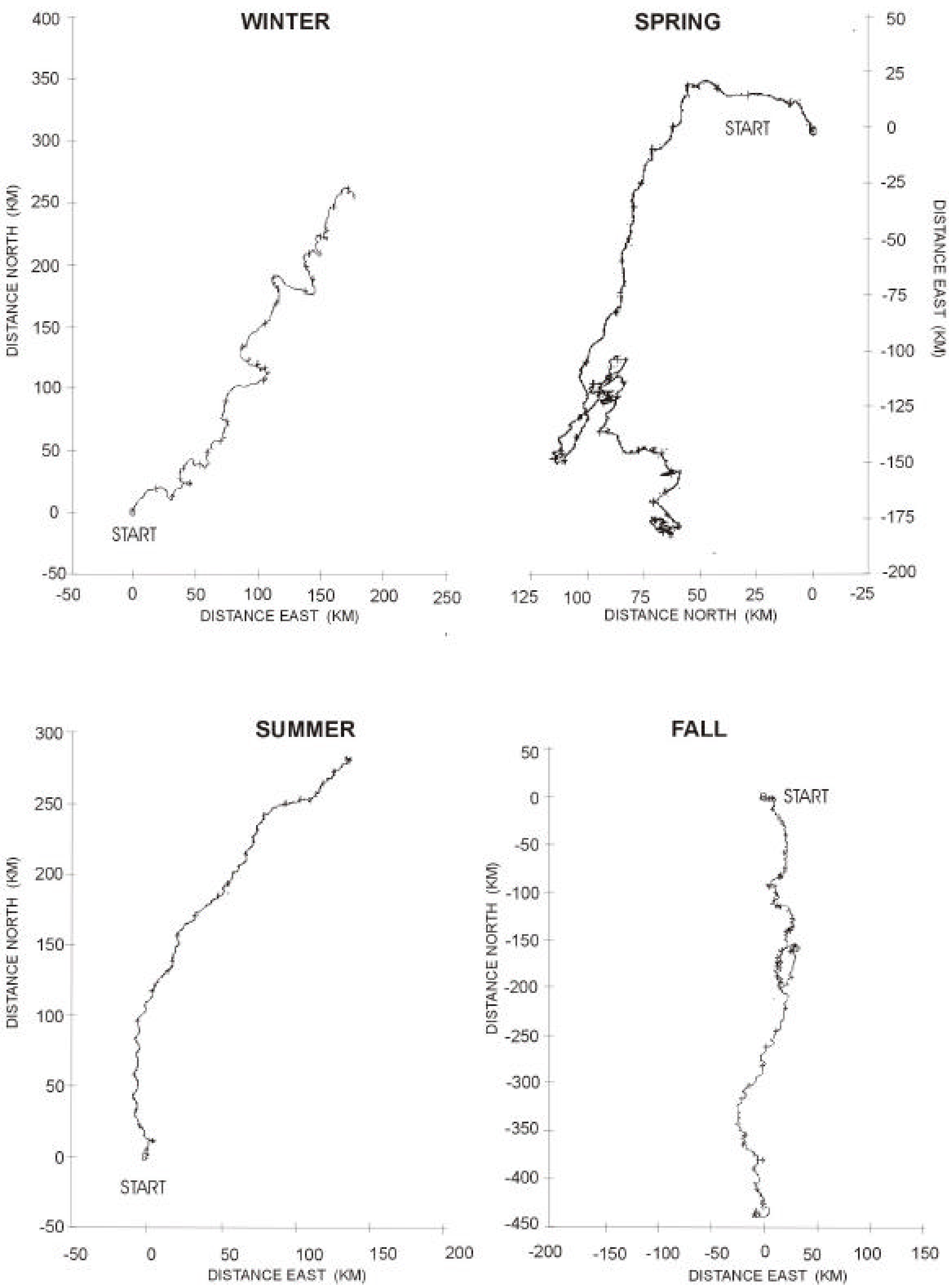


Figure 2.3–20 Progressive Vector Diagrams of Currents at Mid-Depth at White Rose

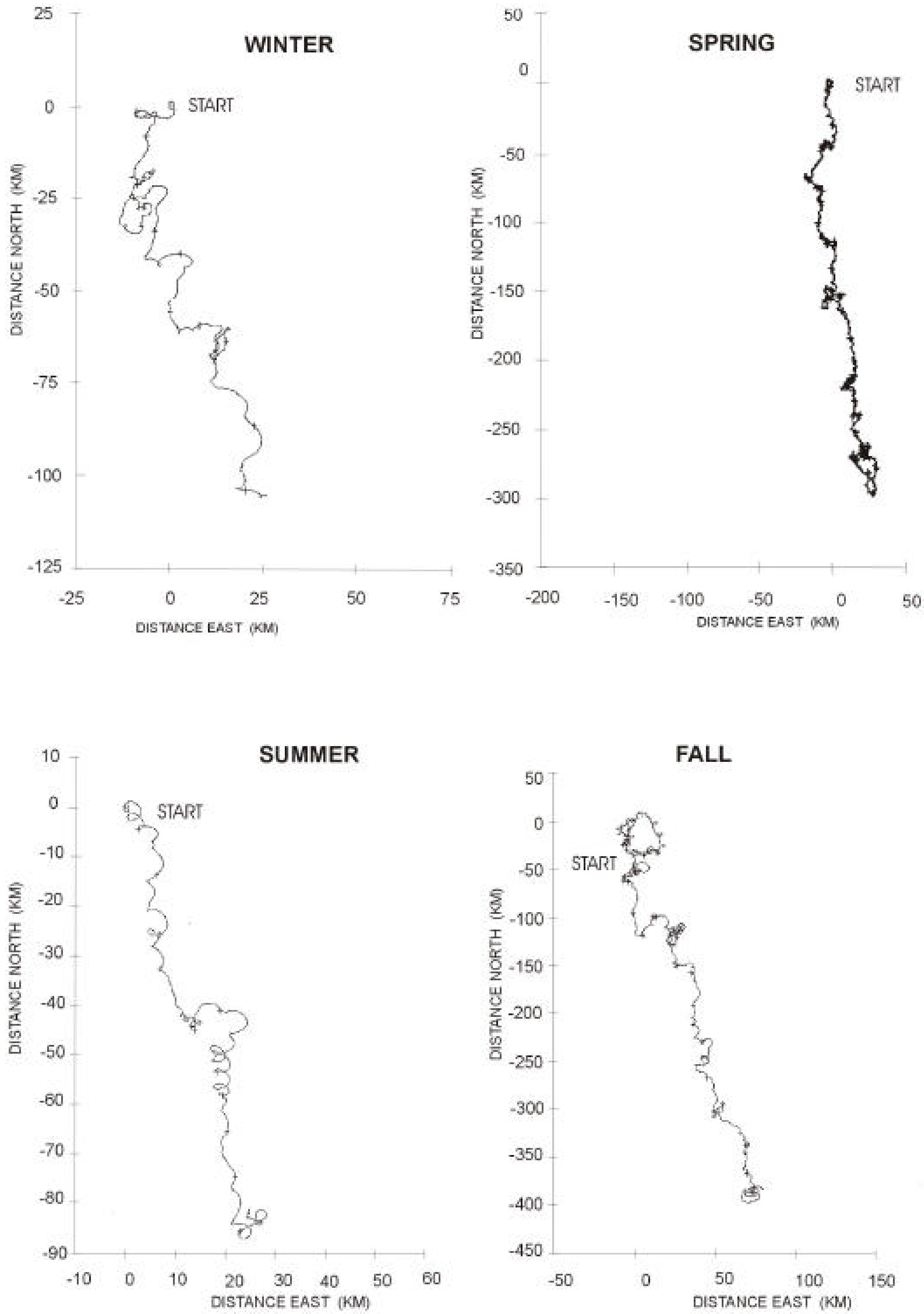
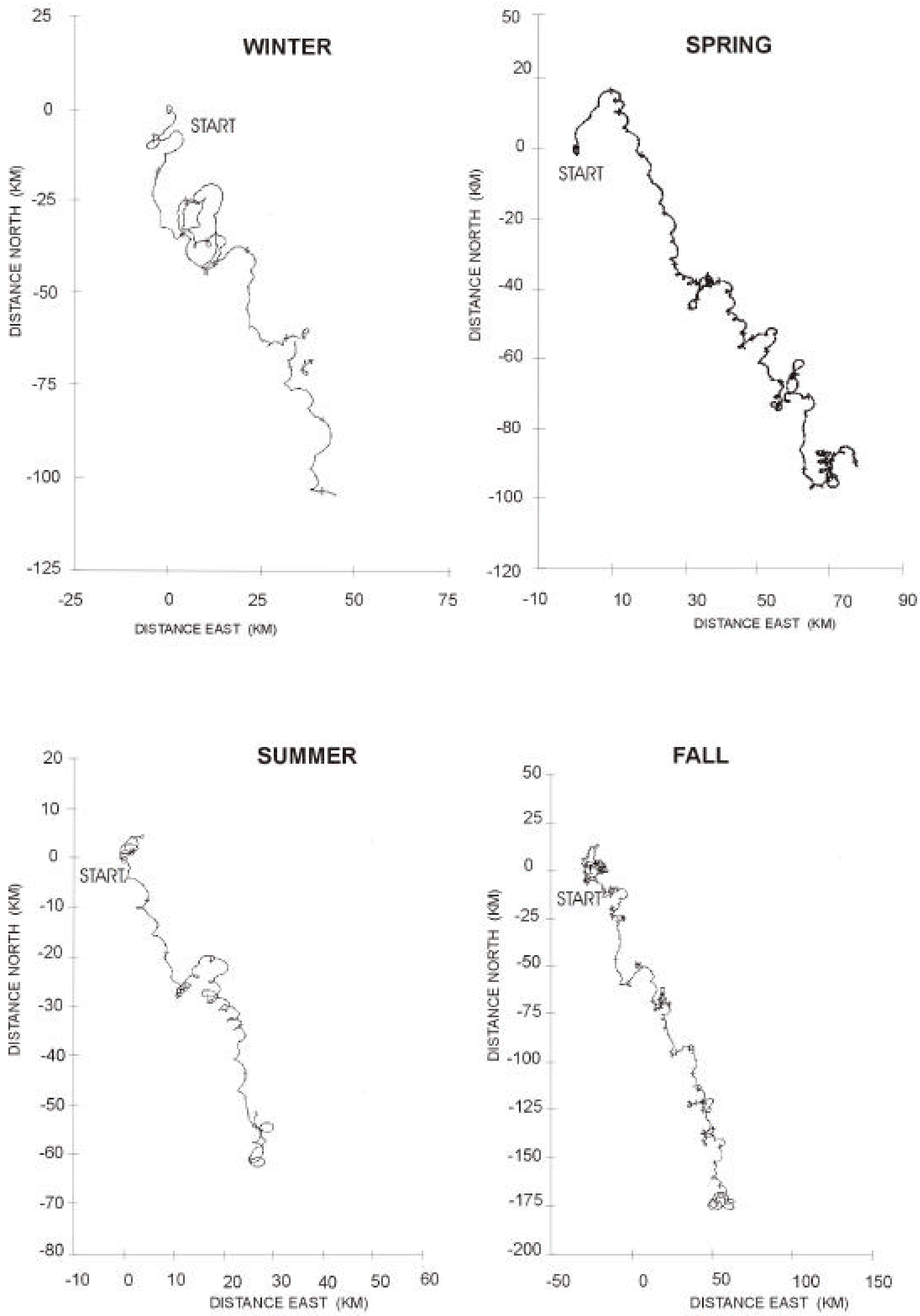


Figure 2.3–21 Progressive Vector Diagrams of Near Bottom Currents at White Rose



The predominant current directions for each month are shown in Table 2.3-10. A notable feature is that the current in the surface waters is often in a different direction than those at mid-depth, indicating that a density boundary occurs at some depth between the two levels. There are also some direction changes between mid-depth and near bottom, but the changes are not as pronounced. For instance, at White Rose L-08 in April 1999, the current was northwest at 20 m, south at 60 m, and southeast at 111 m (Table 2.3-10).

Tang and Bellineau (1994) deployed a bottom-mounted acoustic doppler current profiler on the northern Grand Banks for 70 days from mid-March to early July, 1990. They found that the current structure was a two-layer flow with currents of similar magnitudes, but opposite directions in the two layers. The most prominent vertical structure appeared in the inertial frequency band. The current decreased with depth until it reached a minimum at 63 m and then increased. The mid-surface layer depth was at 55 m in April 1990 and decreased to 40 m in June as a result of seasonal warming.

The currents at White Rose are comprised of semi-diurnal and diurnal tidal currents, direct wind driven currents, inertial currents, geostrophic currents, and low frequency mesoscale currents resulting from such potential features as meteorological disturbances, meanders and eddies, and propagation of continental shelf waves.

2.3.4.5 Tidal Currents

The major tidal constituents for each of the data sets are presented in Table 2.3-11 as resolved by the standard harmonic analysis software programs (Foreman 1978) used by Canadian oceanographers. M_2 and S_2 are the major semidiurnal (highs and lows twice daily) and O_1 and K_1 are the major diurnal (highs and lows once daily) constituents. In the near surface waters, M_2 has the largest contribution, with a maximum amplitude of 7.0 cm/sec and a tidal ellipse orientation of 269º at White Rose N-30. In the data sets with strong currents in specific directions, the tidal effects appeared to be negligible and could not be adequately resolved. At mid-depth, the lunar constituent K_1 was often of the same order of magnitude as M_2. The largest amplitudes resolved for M_2 (5.8 cm/sec) occurred at White Rose L-08 and the largest amplitude resolved for K_1 (5.3 cm/sec) occurred at White Rose A-90 and E-09. M_2 had a tidal ellipse orientation of 275°, and K_1 has a tidal ellipse orientation of approximately 70°.

Near bottom, the largest amplitude for M_2 was at White Rose L-08, with a value of 6.1 cm/sec orientated at 284°. The largest amplitude for K_1 was 5.1 cm/sec in direction 87° at White Rose A-90.

Table 2.3–11 Tidal Constituents (cm/s) at White Rose as Resolved from The Current Data Sets

Well Site	M_2	S_2	K_1	O_1
Surface				
White Rose N-30	7.0	1.9	5.1	2.8
White Rose A-17	0.9	0.5	1.5	1.4
White Rose L-08	1.6	0.8	1.8	2.6
White Rose E-09	4.5	1.2	4.3	1.8
White Rose J-49	4.2	1.6	2.9	2.6
White Rose L-61	4.9	1.9	3.8	3.1
White Rose N-22	1.7	0.7	1.8	1.6
Trave E-87	1.1	0.4	2.3	0.8
Trave E-87	1.3	0.9	3.3	1.4
Mid-Depth				
White Rose N-30	0.8	0.6	1.3	1.3
White Rose L-08	5.8	2.2	4.4	3.0
White Rose A-90	5.4	2.0	5.3	3.2
White Rose E-09	5.2	1.3	5.3	2.9
White Rose E-09	4.8	2.3	3.3	2.5
White Rose E-09	1.4	1.0	1.2	1.2
White Rose J-49	5.5	2.8	3.9	3.8
White Rose N-22	4.6	1.9	4.0	2.6
Trave E-87	0.2	0.3	2.3	0.8
Trave E-87	0.4	0.2	1.0	0.4
Bottom				
White Rose L-08	6.1	1.4	4.8	3.0
White Rose A-90	5.0	1.8	5.1	3.0
White Rose E-09	2.7	1.0	4.0	2.0
White Rose E-09	5.7	2.0	3.8	2.5
White Rose J-49	5.3	2.3	3.7	3.6
Trave E-87	0.3	0.1	1.1	0.3
Trave E-87	0.2	0.3	1.0	0.7

M_2 = Major twice–daily high tidal constituent
S_2 = Major twice–daily low tidal constituent
K_1 = Major once–daily low tidal constituent
O_1 = Major once–daily high tidal constituent

2.3.4.6 Wind Driven Currents

Wind driven currents are a dominant feature of the circulation on the Grand Banks. The episodes of stronger currents are usually associated with the passage of storms. Wind blowing over the ocean surface produces two different types of responses in ocean currents. The direct wind driven component in the surface waters has a magnitude of approximately 3 percent of the wind speed and in a direction of 20 to 45° to the right of the driving force of the wind. This wind driven current has a synoptic period of 2 to 10 days. The other wind effect is an ocean response through strong inertial motions to the passage of storms. Due to the Earth's rotation, the current is always in a clockwise direction in the Northern Hemisphere. Over the northern Grand Banks, the inertial period is approximately 16.5 hours. The strong 80 cm/sec currents found in September at White Rose in the near surface waters are the result of the passage of autumn storms at a time when the water is still strongly stratified. During winter, the effects of storms can be seen throughout the water column, but they are of lesser amplitude.

2.3.4.7 Variabilities

The important driving forces of the current system at White Rose include the surface wind stress, tidal forces, buoyancy fluxes, and the large-scale circulation and interactions associated with the Labrador Current and the North Atlantic Current. Wind stress influences the flow in two time scales; synoptic periods of the order of 2 to 10 days assorted with severe storms, and the inertial period of 16.4 hours. Wind stress provides the major driving force of currents on the Continental Shelf, with a distinct annual cycle of comparatively strong winds in fall and winter, and weaker more variable winds in spring and summer.

Buoyancy fluxes associated with large freshwater inputs produce strong density gradients leading to pressure gradients that drive along-shore currents. The outer branch of the Labrador Current exhibits a distinct seasonal variation in flow speeds (Lazier and Wright 1993) in which the mean flows from September to October are nearly twice as large as the mean flows in March and April. The large variation in density on the shelf results from increased freshwater input from melting ice and freshwater run-off taking place upstream in the spring and summer.

Offshore eddies and rings have an important influence on the circulation over the Continental Slope. Interactions between the Labrador Current and eddies of the North Atlantic Current system will influence the flow along the southeastern section of the Grand Banks, as evident in the drifter tracks. When a Gulf Stream ring encounters a sloping bottom, it radiates low-frequency energy in the form of topographic Rossby waves with characteristic periods of 10 to 30 days (Louis et al. 1982). On approach to the shelf, the wave energy is strongly reflected by the Continental Slope and scattered into baroclinic modes trapped to the shelf edge such that little energy penetrates onto the shelf (Smith and Schwing 1991). However, the resulting redistribution of the density field may have an influence on the currents near the shelf edge. Voorheis et al. (1973) have identified over 30 eddies on the central part of the Continental Slope along the eastern margin of the Grand Banks from an analysis of historical oceanographic data sets going back to the 1920s. The eddies were mostly counterclockwise, with typical speed of 25 to 30 cm/sec and with an average size of 102 km in diameter. Meanders had typical lengths of 275 km in the along-stream direction, and about half this distance in the cross-stream direction.

White Rose is situated far enough north on the Grand Banks to avoid any direct effects from the eddies and meanders on the southern part of the banks. During years when the northern boundary of the North Atlantic Current is further north than usual, as seen in the satellite sea surface temperatures (Figure 2.3-22) for April 8, 1999, there is a potential for indirect effects.

2.4 WIND AND WAVE EXTREMES

This section presents the extreme wind and wave estimates calculated by Oceanweather for the White Rose development on the Grand Banks of Newfoundland. All extremes are specified for recurrence intervals of 1-yr, 10-yr, 50-yr, and 100-yr. All wind speeds refer to the 10 m height. The wind speed parameters are:

- 1-h mean (WS);
- 10-min mean;
- 1-min mean;
- 15-s mean; and
- 3-s mean.

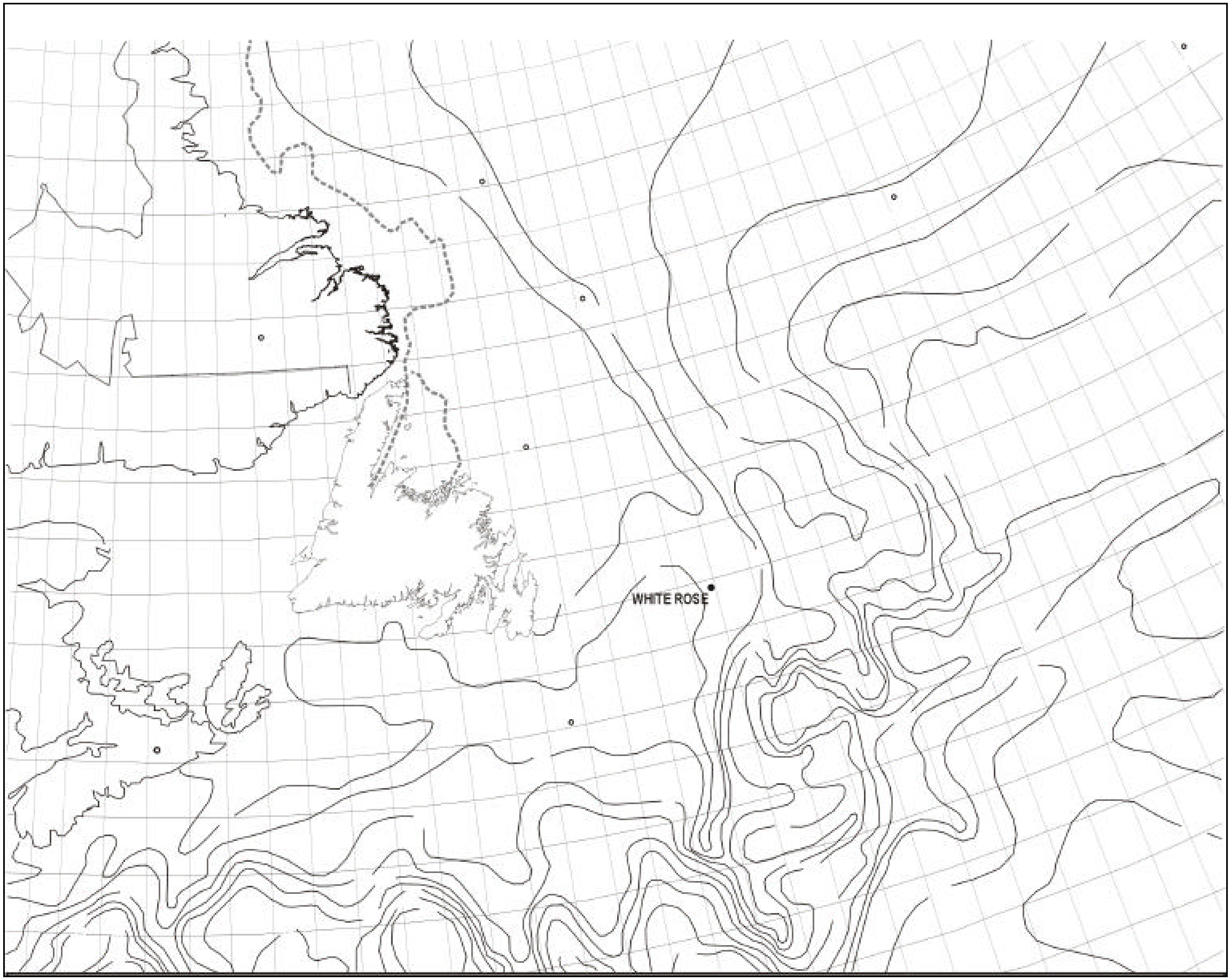
The wave parameters are:

- significant wave height (SWH);
- maximum wave height (HS); and
- spectral peak period (TP).

The extremes were derived from the results of the recently completed 40-yr continuous hindcast of the North Atlantic Ocean supported by Atmospheric Environment Service (AES) of Environment Canada. This hindcast project (henceforth referred to as AES40) was carried out by Oceanweather between 1997 to 1999 in collaboration with V. R. Swail of the Climate Division of AES. The AES40 hindcast model has a grid spacing of 0.625° in latitude by 0.833° in longitude. For the present analysis, the hindcast time series for the grid point nearest White Rose was used, namely grid point #5622 located at 46.875N, 48.333W, which is located approximately 20 km (10 nautical miles) due west of White Rose. AES40 used deep-water physics, therefore, any slight difference between the water depth at the White Rose and the grid point is not important in this analysis.

The following subsections of this report provide a description of the AES40 hindcast, a description of the methodology used to arrive at the extremes and a discussion of the extremes themselves.

Figure 2.4–1 Sea Surface Temperatures on April 9, 1999



2.4.1 Review of Hindcast Approach

By the beginning of the 1980s, the so-called hindcast approach to the specification of environmental design data for the design of offshore structures was well established. For example, a U.S. National Research Council Marine Board review (National Academy of Sciences 1980) concluded that: "Hindcasting techniques using verified environmental models coupled with statistical treatment of occurrences of natural events gives an appropriate and adequate technical basis for determining environmental exposure."

With regard to specification of the environmental extremes of marine surface wind and sea state, the hindcast approach had already been particularly well developed and verified during the 1970s by virtue of a number of dedicated offshore industry-sponsored field measurement and hindcast model development programs.

The hindcast method consists of the following steps:

- a survey of historical meteorological data, to identify the most severe storms of the relevant type or types responsible for extremes that have occurred within as long a period of history as possible;
- for each storm selected above, a threshold of intensity, numerical hindcast of the time history of the sea state and currents on a grid of points representing the basin;
- calculation of the expected extreme wave heights and associated properties, and currents for each storm at each point; and
- extrapolation of the hindcast and calculated extremes through the process of extremal analysis, which provides estimates of extremes associated with specified return periods (return period is the average interval in years between events equal to or greater than the associated extremes). Such data are then used by ocean engineers for the specification of design loads on structures.

The hindcast of an individual historical storm consists of two basic steps. First, the time and space evolution of the surface marine wind field must be specified as accurately as possible, a process which usually requires the reanalysis of historical meteorological data by experienced meteorologists with the aid of calibrated objective analysis procedures or models. The wind fields are used to drive previously calibrated ocean response models (for example, a spectral wave model, storm surge model, mixed layer current model) as the second part of the hindcast process. Contemporary wave hindcast studies use numerical spectral wave models, which resolve the full directional spectrum and model processes of wave growth under the action of the wind, wave dissipation, wave-wave interaction and wave propagation. First generation (1G) models were introduced in the 1960s and were used in the first major hindcast studies. Second generation (2G) and third generation (3G) wave models were introduced during the 1980s, but as discussed below, it does not necessarily follow that the later the model generation, the better.

The hindcast approach was first used in earnest in the analysis phase of the Gulf of Mexico Ocean Data Gathering Program (ODGP) (Cardone et al. 1976). Since ODGP, the hindcast approach has been widely adopted by the offshore and coastal engineering communities as a way to develop reliable extreme wind, wave, surge and current design estimates for offshore and coastal structure design. The method was applied to develop definitive design wave extremes for the Hibernia Grand Banks development in the early 1980s (see, for example, Cardone et al. 1989). Later projects have been carried out within the context of major joint industry projects.

Major hindcast studies of both the operational and storm climates have addressed the South China Sea (SEAMOS, Cardone and Grant 1994) and the west coast of Africa (WAX, Cardone et al. 1995a). SEAMOS involved the hindcast of 10 continuous years (1980-89) and 207 storms, with a 3G shallow model adapted on a 25-km grid (SEAMOS is the first application of a 3G wave model to extreme wave climate assessment). SEAMOS was updated during 1999. The North European Storm Study (NESS; Peters et al. 1993), which included the hindcast of 25 continuous winters (1964 to 1989) with a 2G wave model, has been completely rehindcast and updated to 1995 with a 3G shallow water wave model. Similarly, a previous study that used a 1G model to assess the extreme wave climate off the East Coast of Canada was recently updated to include the many severe storms observed through 1995, with all previous and new storms (a total of 82 events between 1954 to 1995) rehindcasted with a 3G model. The updates to both the NESS and CCC-91 studies used a new interactive wind workstation to hindcast the surface winds fields (Cox et al. 1995). The interactive wind workstation greatly reduces the degree of manual labour over classical kinematic analysis required to develop the most accurate wind fields possible for a given historical data set. Model verification studies conducted as part of the CCC-91 and NESS updates suggest that 3G models provide slightly greater wave heights and lower periods than 1G and 2G models for the same wind fields. This result, combined with the increased severity of storms observed off the Northwest Europe and the East Coast of the US in recent years, has resulted in increases in the extreme wave climate specified in the update studies by about 10 percent over earlier estimates in some deep water offshore areas. Additional joint industry projects completed by Oceanweather within the past decade, which addressed primarily wind and wave extremes, include GUMSHOE (Gulf of Mexico hurricane extremes), WINX (Gulf of Mexico winter storms), BSCOMP (Bering Sea), CSCOMP (Chukchi Sea), BOMOS (Brazil), RASMOS (Russian Arctic Seas), SIMOS (Sakhalin Island), NILDOS (Nile Delta).

2.4.2 Skill of Hindcast Extremes

ODGP and GUMSHOE included substantial hindcast model validation studies because wind, wave, surge and current measurements had been made in some notable historical Gulf of Mexico storms (for example, Audrey in 1957; Bertha in 1957; Carla in 1961; Camille in 1969; Edith in 1971; Delia in 1973; Frederic in 1979; Danny in 1985; Juan in 1985). Validation of the ODGP hindcast model against these tropical cases, together with validation against measurements acquired in severe extratropical cyclones (for example, Reece and Cardone 1982), demonstrated that ODGP, when driven by high-quality winds, typically specifies peak significant wave height (SWH) at an arbitrary site in a storm with bias of less than 0.5 m, mean absolute error of less than 1.0 m and scatter index of 10 to 15 percent (scatter index is 100 x sd/avg where sd is the standard deviation of differences between hindcast and measured peak wave heights and avg is the average of measured heights in the validation population of heights). The period and directional properties of peak storm generated seas appear to be specified with comparable skill.

The ODGP model was raised to effectively 2G standards in the mid-1980s (thereafter referred to as ODGP2). ODGP2 has been applied in dozens of studies worldwide to develop extreme and operational wave statistics and continues to provide skillful hindcasts in a wide range of wave regimes, including Arctic and sub-Arctic basins, mid-latitude NH and SH regimes, tropical cyclone regimes and subtropical regimes such as the Gulf of Mexico, South China Sea and Arabian Gulf (for example, Cardone et al. 1989; Cardone and Ewans 1992; Eid et al. 1992). Oceanweather has developed and tuned its own version (OWI3G) of the community 3G wave model known as WAM model (WAMD1 1988) and achieved excellent results with this model in both tropical and extratropical settings. The alternative wave model physics of OWI3G is described by Khandekar et al. (1994) and Forristall and Greenwood (1998).

OWI3G was used to validate hindcasts against many of the same storms used to validate ODGP, as well as more recent storms measured by US and Canadian buoys. The mean errors in significant wave height and spectral peak period was found to be 0.13 m and 0.27 sec, respectively. The root mean square error was 0.98 m and 1.64 sec, and the scatter index was 14 and 15 percent, respectively. The skill seems to be invariant with wave height, at least up to a significant wave height of about 12 m, with a tendency to slightly underestimate peak sea states in the most extreme storms in which SWH exceeds about 12 m. This under-specification in peak states is also observed with other contemporary wave models (Cardone et al. 1996).

2.4.2.1 Continuous 40-Year Hindcasts

In most of the joint industry projects noted above, platform survival type design criteria were typically developed from hindcasts of storm populations drawn from a 20 to 50-yr period of history and of the type responsible for extreme loads in a given area, while operational criteria were derived from hindcasts of a few continuous years. Within the past few years, Oceanweather have explored merging these two approaches by developing long-term hindcast databases for whole basins or the globe itself, spanning 40 years or more, from which both extreme and operational criteria may be derived at any arbitrary location. Such a database would also be ideal for simulation of a wide range of offshore operations, including assessment of trans-basin wet or dry structure tows.

As a first attempt, Oceanweather's GROW (Global Reanalysis of Ocean Waves) database was generated in early 1998 on a global grid using its ODGP2 wave model. The grid spacing is 1.25° latitude by 2.5° longitude. Winds were specified directly from the new NOAA/NCAR 40-yr (1958 to 1997) Global Reanalysis Project (NRA). NRA wind fields do not resolve tropical cyclones and there are biases in extratropical storms. Nevertheless, GROW has been shown to provide reasonably accurate global significant wave height statistics and estimates of recent trends in global wave climate. Oceanweather has also used GROW successfully to develop initial estimates of site-specific extremes and normals. Where local sea state measurements and/or satellite altimeter data are used to quantify and remove biases in GROW time series of significant wave height, the normal and extremes statistics derived are remarkably similar in deep water offshore areas to those developed by detailed hindcast studies. GROW is described in a paper submitted (and in review) to the Journal of Geophysical Research (A Global Wave Hindcast over the Period 1958 to 1997 (Swail and Cox 2000)).

GROW is not considered an optimum solution because of its low spatial resolution, the aforementioned tendency of GROW to under-specify sea state peaks in intense extratropical cyclones and the failure of the NRA input winds to resolve tropical cyclones. These issues were addressed and corrected for the North Atlantic Ocean in a 40-yr hindcast of the North Atlantic completed in 1999 as funded by AES of Environment Canada. This work is documented in a paper accepted for publication (Swail and Cox 2000). In AES40, the wave model resolution was increased by decreasing the model grid spacing to 0.625° latitude by 0.833° longitude, a 3G wave model (OWI3G) was used, the wind fields of all major storms were reanalyzed interactively using Oceanweather's interactive wind workstation system, and all tropical cyclone winds were modelled using Oceanweather's mesoscale model (after reanalysis of individual storm tracks and properties from raw source data) and blended into the basin-wide wind fields. AES40 was a 10,000-labour hour effort and a nine-month computing exercise, so this approach is not readily extendable to global coverage in the foreseeable future.

2.4.2.2 Maximum Skill in Continuous Hindcasts

The recent SWADE hindcast study was carried out using data acquired off the US East Coast (Cardone et al. 1995b). It demonstrated that where surface wind fields are specified using kinematic reanalysis techniques, well calibrated wave models may specify the evolution of significant wave height with negligible bias and scatter near the lower limit set by accuracy and sampling variability in the wave measurements. Kinematic reanalysis techniques take advantage of the enhanced data coverage in areas of dense buoy and/or offshore platform measurement arrays (for example, off the east and west coasts of North America and in and around the North Sea). Within the dense buoy array, the significant wave height scatter index (SI) of 14 percent is unprecedented for continuous hindcasts. However, the mean negative error of about 0.4 s in peak period is apparently a real characteristic of this hindcast and may be caused by use of 3G wave model physics. The WAM Cycle 4 model was used for the SWADE hindcast.

Errors in hindcasts validated against wave measurements on the periphery of the SWADE array increased to levels of 18 to 25 percent for significant wave height SI. This is probably more typical of continuous hindcasts of mid-latitude extratropical weather regimes in the open ocean with kinematically reanalyzed winds. Errors were generally larger, in the range of 26 to 40 percent, when the same hindcast was repeated with wind fields produced operationally at major analysis centres at the time (October 1990).

As part of a AES40-yr hindcast study of the North Atlantic Ocean, Swail and Cox (2000) evaluated the skill in deep water hindcasts of the North Atlantic Ocean with OWI3G driven by alternative estimates of the surface marine wind field. The evaluation of the hindcast made using unmodified NRA winds against all buoys moored in deep water offshore the US and Canadian East Coasts and off Northwest Europe indicates less skill than provided by kinematically reanalyzed winds, with significant wave height SI 26 percent overall, which is at the lower end of the range exhibited by wave hindcasts driven by the operational winds in SWADE. However, the significant wave height bias was satisfyingly small. The negative bias in wave period noted above is also evident in these hindcasts.

The AES40 hindcast made with reanalyzed winds showed an 8 percent reduction in the significant wave height SI at the positions of the buoys. Validation over the whole basin against satellite altimeter significant wave height data indicated a significant wave height bias of .05 m and significant wave height SI of only 21 percent. These evaluations indicate that the NRA reanalysis wind field products are a substantial improvement in wind field accuracy over operational wind fields produced just a few years ago.

While paired difference statistics are useful measures of skill, the comparisons of statistical distributions of significant wave height are good indicators of the reliability of the continuous database for design. Swail and Cox (2000) show excellent agreement between AES40 hindcast and buoy significant wave height distributions at all well exposed deep water buoys in terms of Quantile-Quantile scatter plots, including the AES buoys on the east coast. Finally, it is noted that the estimate of 100-yr significant wave height derived from AES40 at Hibernia is within 0.3 m, or 2 percent of the average of such extremes derived in several previous dedicated storm hindcast studies.

2.4.3 Extremal Analysis Results

The extremes for return periods of 1, 10, 25, 50 and 100 years derived from the hindcasts from AES40 at grid point #5622, located at 46.875N, 48.333W, are provided in Table 2.4-1. For wind, the extremes are given for the following parameters: 1-h mean, 10-min mean, 1-min mean, 15-s mean gust and the 3-s mean gust. For waves, the extremes are given for significant wave height, maximum wave height and spectral peak period.

Table 2.4–1 Extremes at White Rose Location Using AES40 Grid Point 5622 (46.875N, 48.3333W) - All Months and Years Combined

Return Period (years)	Wave (m)			Wind (m/s)				
	Significant wave height	Maximum wave height	Associated spectral peak period	1-h mean	10-min mean	1-min mean	15-s mean	3-s mean
1	10.5	19.7	13.5	23.6	25.0	28.8	31.2	33.7
10	12.7	23.8	14.9	27.7	29.4	33.8	36.6	39.6
25	13.5	25.2	15.4	28.8	30.5	35.1	38.0	41.2
50	14.1	26.3	15.8	29.7	31.5	36.2	39.2	42.5
100	14.7	27.4	16.1	30.5	32.3	37.2	40.3	43.6

The analysis involved the following steps. First, the six-hourly AES40 time series at grid point #5622 was computer scanned for occurrences of distinct peaks of significant wave height (SWH) above 9.5 m within distinct 24-h time windows; 80 such peaks were found (Appendix 2.C). A similar scan based upon a wind 1-h mean threshold of 24 m/s was made and 42 peaks were found (Appendix 2.B). These "storm peak tables" are in rank order by the variable scanned, and for each event include a number of hindcast model parameters such as total variance, vector mean wave direction and peak period of the total sea state, the same parameters for sea and swell partitions, the first and second spectral moments, two different measures of angular wave spreading and estimates of the maximum individual wave height (HM) and crest heights (HC) within the event. The maximum wave and crest heights are estimated from the entire time history of the event within each storm window. The last two entries in the storm peak tables give the ratios HM/SWH and HC/SWH for each event, computed using Borgman's integral approach that takes into account the time scale of the storm build-up and decay in each event. For example, the highest ranked storm (February 17, 1962) yields a hindcast peak of 13.7 m for the significant wave height (SWH), a computed value of 25.5 m for the maximum individual wave height (HM) and a ratio HM/SWH of 1.86, but in general this ratio varied from as low as 1.81 to as high as 2.03.

The temporal distribution of the peaks of significant wave height over the adopted threshold is shown in Figure 2.4-1. There is interesting decadal scale variations in severe storm frequency, which suggest that extrapolations based upon shorter historical records could be misleading.

Next, the peaks for significant wave height, maximum individual wave height, and 1-h mean wind were ranked above a selected threshold and fitted to several distributions. The fits for three distributions (Gumbel, Borgman and Weibull) to the 42 wind peaks are shown in Figure 2.4-2, and the fits for the 80 significant wave height peaks are shown in Figure 2.4-3. Other thresholds were attempted, but it was judged that the best fits were for these thresholds. Within this threshold, the best fits were provided by the GUMBEL distribution, which also yielded slightly more conservative extremes than the other distributions.

Figure 2.4–2 Storm Peaks of Significant Wave Height Greater Than 9.5 m Over 40 Years

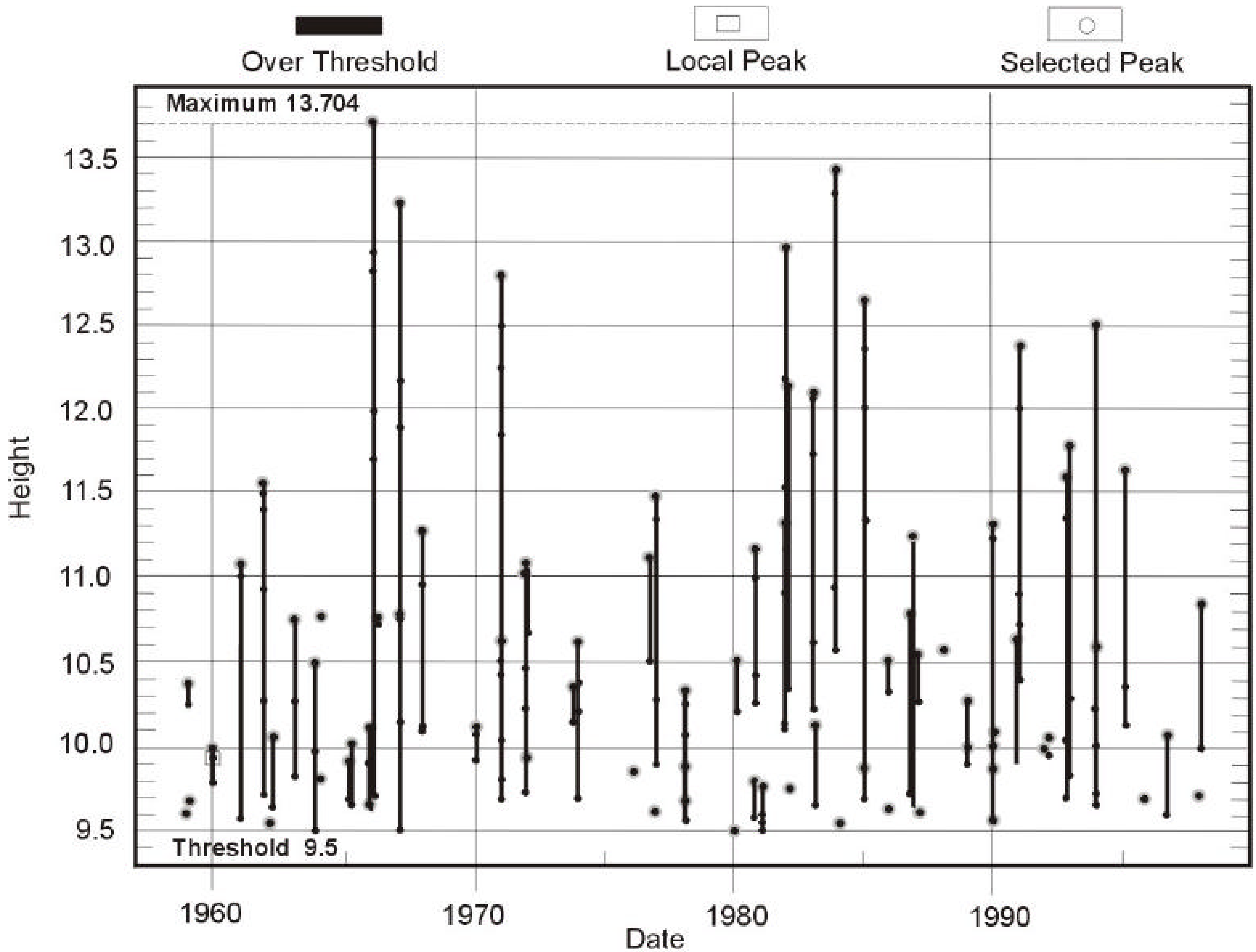


Figure 2.4-1 Storm Peaks of Significant Wave Height Greater Than 9.5 m Over 40 Years

Figure 2.4–3 Extremal Distributional Fits on Maximum Wind Speed Peaks Over Threshold of 24 m/s

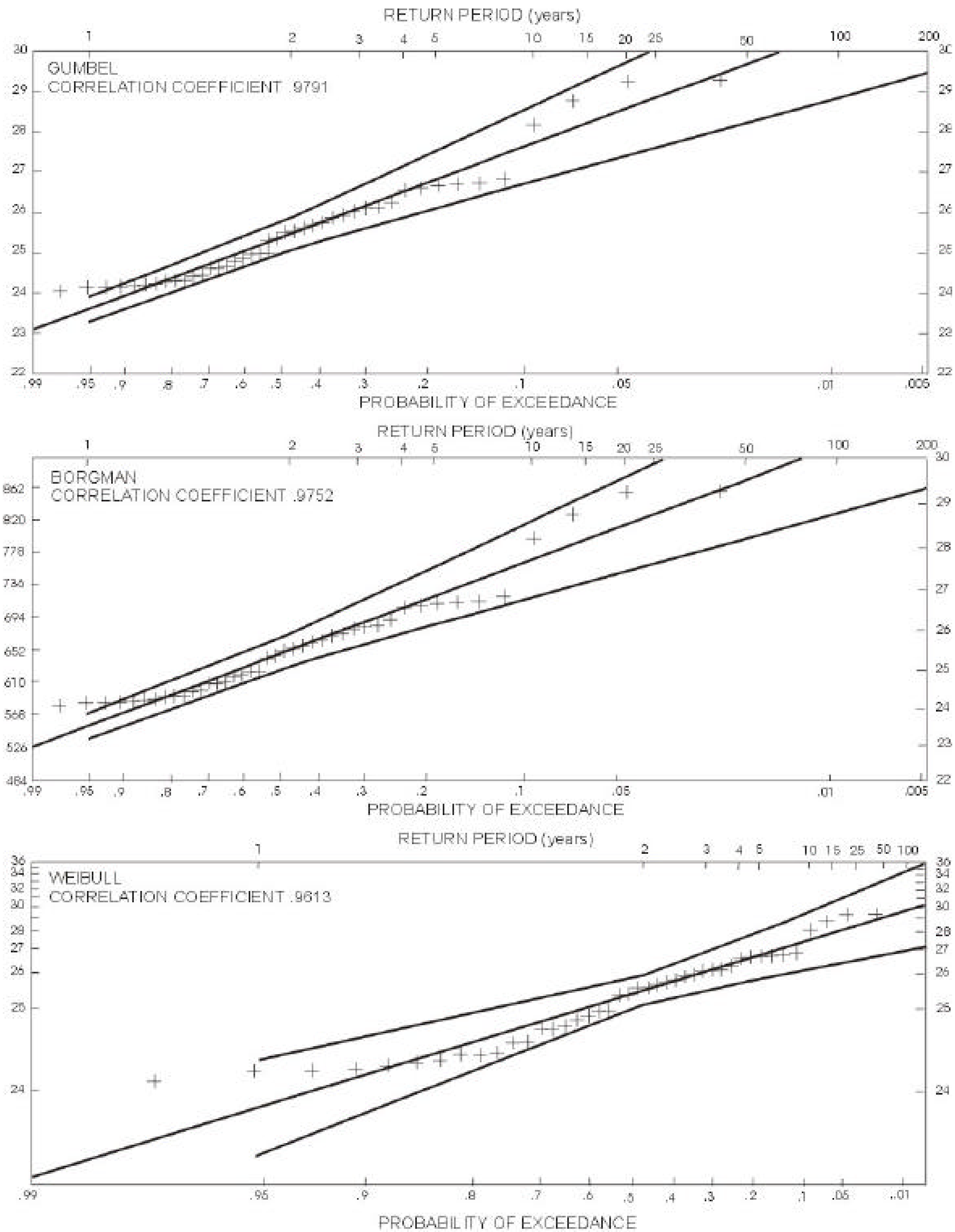


Fig 2 4 2 cdr

Figure 2.4–4 Extremal Distributional Fits on Maximum Significant Wave Height Over Threshold of 9.5 m

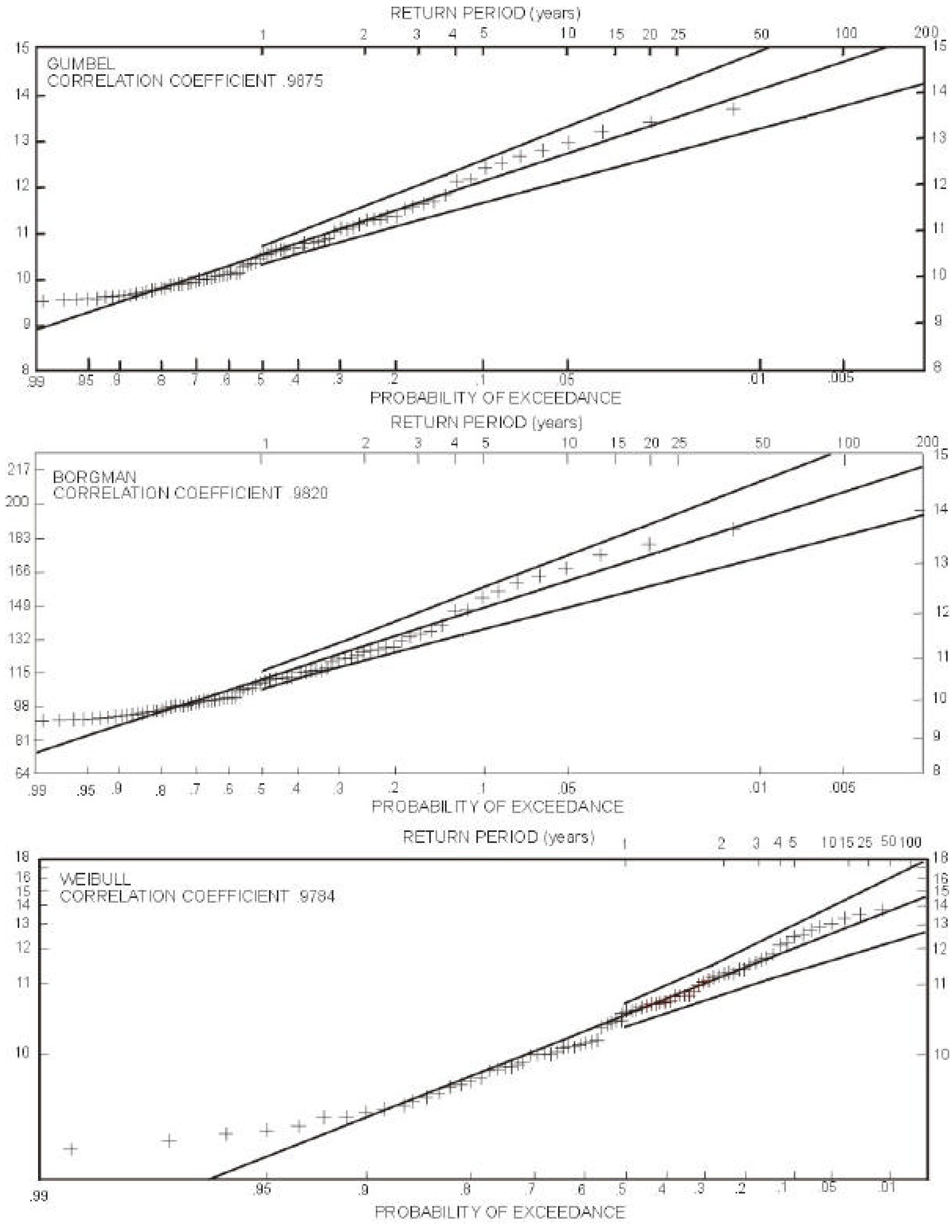


Fig 2 4 3cdr

The spectral peak periods associated with the return period estimates of significant wave height included in Table 2.4-1 are derived from maximum wave height and spectral peak period regression fits developed from the 80 storm peaks.

2.4.4 Discussion of Results

The AES40 hindcast naturally defines the population of storms responsible for extreme winds and sea states at White Rose. The accuracy of the AES40 hindcasts of these storms should be at least as accurate as the discrete storm hindcasts made in dedicated studies of the Canadian East Coast over the past decade or so for three basic reasons. First, the AES40 wind field analysis benefited from these previous studies because the kinematic analyses carried out for individual storms were assimilated into the AES40 continuous wind fields. Second, if by some chance, an extreme storm was somehow missed in a previous study, it would be naturally included in the 40-yr continuous hindcast. Third, the wave model used in AES40 has been validated extensively and specifically in recent extreme storms to affect the Canadian East Coast, such as the "Halloween Storm" of October 1991 and the "Storm of the Century" of March 1993.

The top ten-ranked hindcast events at White Rose yielded peak storm significant wave heights of 12 m or greater. Three of these storms occurred between 1966 to 1971 and the other seven between 1982 to 1993. All of these storms occurred within the two-month period December 22 to February 23, which is roughly the period of maximum frequency of intense extra-tropical storms responsible for extreme sea states on the Grand Banks peaks. For example, the storm in which the Ocean Ranger sank on February 15, 1982, is included in this population, but it is not the highest ranked event.

With one exception, the peak wind speed (1-h average at 10-m height) exceeded 25 m/s in these storms. The vector mean wave direction associated with the top ranked storm peak wave heights varied between north-northwest to west-southwest. The extremes given in this report are omni-directional rather than sector stratified, but it may be assumed that the design wave will approach from the directional sector defined by the above sector occupied by the top-ranked storms.

The peak period associated with the peak storm significant wave height for the top-ranked events varies between 14.2 and 15.8 s. Since AES40 was run with a 3G type wave model, peak periods are somewhat lower than found in previous studies carried out with 1G or 2G models and there remains some question whether 3G models under-specify storm peak period. It is interesting to note, however, that in the great Halloween Storm of October, 1991, the 'tail of the bank buoy' (44141 in 4,500 m water depth on the Laurentian Fan) measured a peak significant wave height of 14.6 m associated with a spectral peak period of 16.0 s, a combination close to that derived in this study for the White Rose 100-yr sea state.

2.5 SEA ICE AND ICEBERGS

The following is a description of the ice environment surrounding the White Rose development project area. This description uses as its base, information and data published in the Terra Nova Development Environmental Impact Assessment (Petro-Canada 1995). Those data have been updated to include subsequent data and reports from 1996 to 1999. Apart from some small numerical adjustments, most of the regional data and associated descriptions remain unchanged. However, reworking of the site-specific information was undertaken to account for the different ice regime caused by the more easterly location of White Rose.

The White Rose oilfield lies on the eastern slope of the continental shelf, making it susceptible to seasonal incursions of ice. Two different forms of floating ice, sea ice and icebergs, are present in this marine environment. Sea ice is produced when the ocean's surface layer freezes. In the area of White Rose, sea ice is usually loosely packed and pressure-free. Floes are small and generally in advanced stages of deterioration. This permits easy vessel movement. However, sea ice can interfere with iceberg detection and towing operations.

Icebergs are freshwater ice made from snow compacted in a glacier. When the leading edge of a glacier reaches the sea, slabs of ice fall off it, creating icebergs. Grand Banks icebergs originate mainly from the glaciers of West Greenland. Ice management efforts focus on icebergs because they pose a hazard to offshore production facilities.

The description of the ice regime at White Rose provides a description of the databases used, followed by a summary of the characteristics of the sea ice cover, then information on icebergs. Extreme conditions are included because they illustrate how the ice regime varies over time and space. Such variability is important when trying to assess the effect of ice on offshore development. This section concludes with a summary of current ice management practices.

2.5.1 Databases

Regional sea ice data are available from approximately 40 years of ice observations carried out by the Canadian government. Initially, these observations were obtained from airborne reconnaissance. Beginning in the 1970s, satellite images supplemented airborne observations, eventually replacing them as the principal sources of data by the mid-1990s. The data appear in daily and (approximately) weekly composite ice charts produced by the Canadian Ice Services (CIS).

These charts and compilations by Sowden and Geddes (1980), Seaconsult (1988) and Cote (1989), underlie the description of sea ice in this document. Supplementary information on ice movements, thicknesses and floe sizes and their linkages to environmental factors have been obtained from:

- observations made by the offshore oil exploration industry from the 1970s through the 1990s; and
- research programs carried out by the DFO, AES and by the Panel on Energy Research and Development (PERD).

Sea ice data support relatively unambiguous and detailed cross-comparisons dating back to the late 1950s and, with lesser precision, to the second decade of the twentieth century (Hill and Jones 1990).

Data on icebergs are available for an even longer period, dating back some 100 years. The formation of the IIP in 1913 led to the routine compilation of iceberg sightings in areas south of Labrador. Marine vessel reports were the basic data sources initially. Beginning in the 1950s, fixed-wing aircraft assumed the major responsibility for iceberg surveillance. Additional data have been obtained in the last three decades from observations made during oil exploration activities.

Over the years, the IIP has collated and cross-indexed sighting data from all sources to provide updated position maps and estimates of numbers of icebergs crossing 48°N for annual and shorter time frames. Additional coverage beyond the 52°N limits of IIP interest, and inshore areas, has been available for more than two decades from CIS.

The IIP data have been used in most efforts to quantify and understand iceberg behaviour off eastern Canada. These analyses have included daily charts of iceberg positions prepared from recent sightings and radar target positions. Iceberg positions and sizes were deduced using simple models of iceberg drift and deterioration. Unfortunately, the database is not internally consistent because, over time, production procedures, detection technologies, and levels of effort changed. This has constrained analyses of iceberg spatial and temporal trends and their characteristic variations (Petro-Canada 1995).

Since 1989, iceberg survey data for the Canadian East Coast between 45°N and 55°N have been available from Provincial Airlines Ltd. (PAL). These data are particularly notable because the icebergs are visually confirmed after initial detection with radar. The revisit time of these surveys is on average every five days. Thus, iceberg numbers, estimated in defined counting areas, are simple sums of local counts obtained in all surveys during the time period of interest.

The accuracies of such estimates depend on the drift and deterioration rates of all icebergs moving through the area. Average drift speeds of 20 km/d on the Grand Banks and 30 km/d just off the Grand Banks mean that icebergs move completely through the 110 km x 75 km areas defined by the 1° grids within the revisit time. Thus each new count in a grid block yields a new iceberg population.

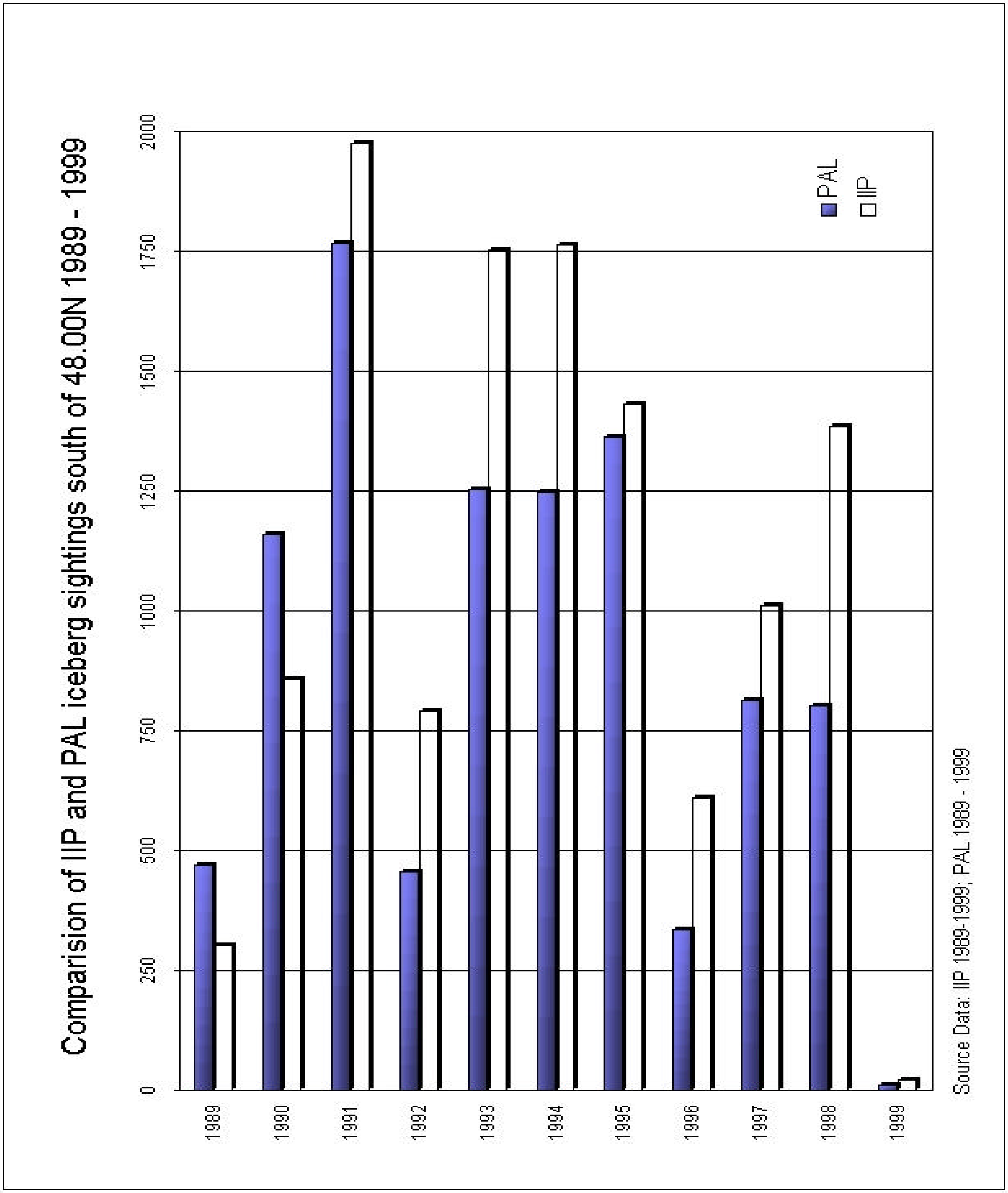
Comparisons of annual total numbers of icebergs south of 48°N indicate that IIP estimates are larger than PAL iceberg counts (Figure 2.5-1). This difference is likely the result of different operating mandates, estimation procedures and uncertainties associated with each survey. For example, there is a real possibility of confusing ships and icebergs in the SLAR-based IIP surveys. The IIP mandate is to advise mariners of the extreme limit of all known icebergs. Under this mandate, any debate on what a particular radar target is, will result in it being identified it as an iceberg.

Under a 1998/1999 PERD initiative, both the IIP database and those from offshore oil exploration have been combined into a single iceberg database. Apart from removing some inconsistencies in formatting and some obvious positional errors, this database provided no new insights into iceberg distributions. However, it has proved useful in providing some insight into iceberg size.

In an effort to be consistent with previous Grand Banks development documentation, the following document bases its description of the regional iceberg environment on both the long-duration IIP database and PAL data obtained for the years 1989 to 1999.

Other iceberg data assessed consisted largely of measurements of physical dimensions and velocities, available as a consequence of numerous monitoring and study programs carried out by the oil industry during exploration activities and in preparation for eventual offshore oil production. These data, together with results obtained from research efforts supported by PERD and the Environmental Studies Revolving Fund (ESRF), form the basis for analysis of the physical iceberg characteristics presented in this document.

Figure 2.5–1 Comparison of IIP and PAL Iceberg Databases, 1989 to 1999



2.5.2 Sea Ice

2.5.2.1 Formation and Growth

Seawater, when cooled through atmospheric heat exchange, increases in density. It then sinks to a depth determined largely by the salinity of the upper ocean. In polar and sub-polar regions, this process eventually produces a relatively well-defined surface layer of water at its freezing temperature. Further loss of heat to the atmosphere causes ice growth. Ice growth is determined by:

- air temperature;
- wind speed;
- sea state;
- levels of snow accumulation;
- magnitudes of heat fluxes from deeper, warmer ocean layers; and
- ice deformation driven by winds and current.

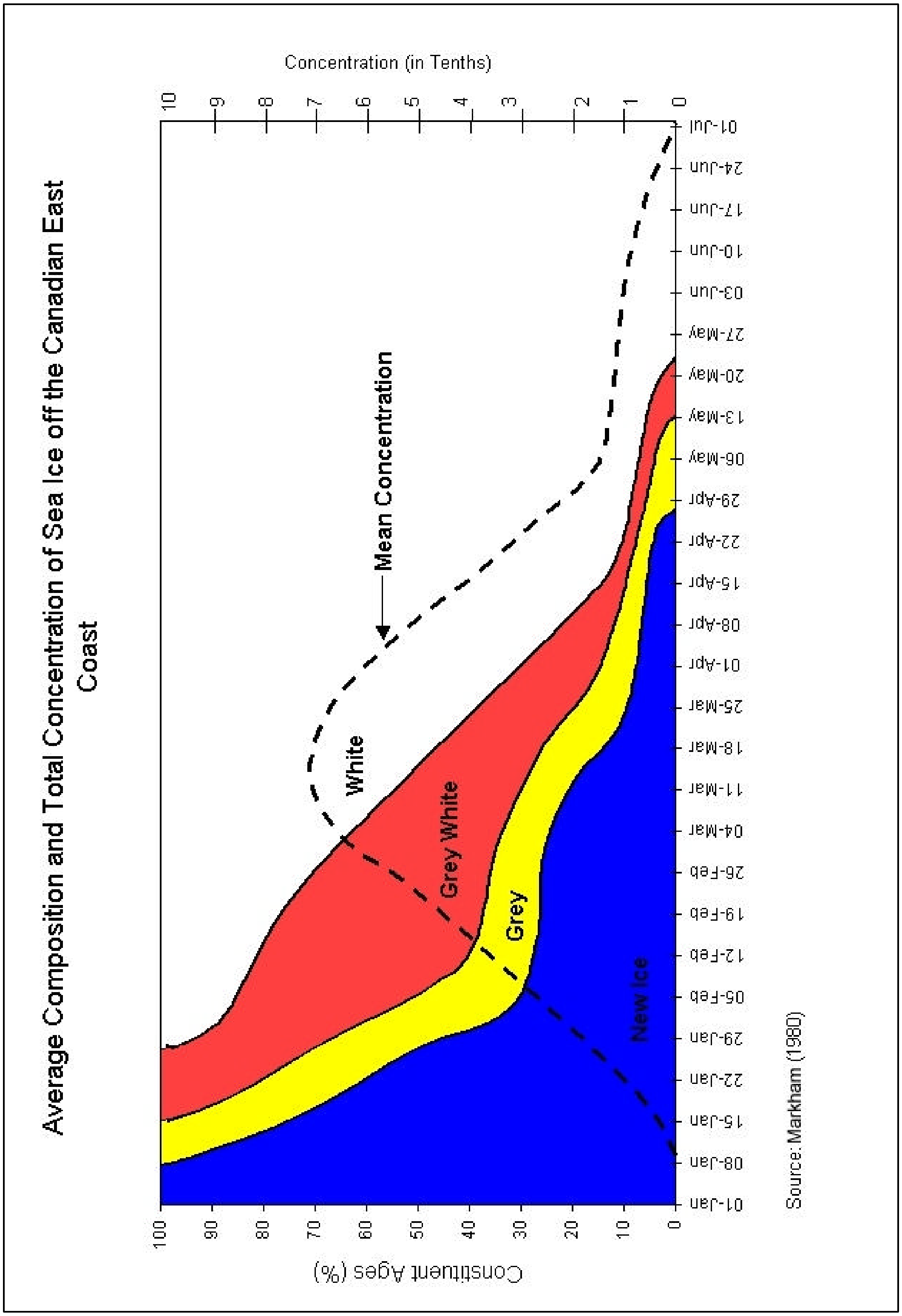
Major categories of sea ice age and thickness are listed in Table 2.5-1. Almost all the ice occurring near White Rose is either young or first year ice, between 30 to 100 cm. Some thicker first-year ice also occurs. Ice thicknesses substantially greater than 100 cm are usually only associated with deformed first-year ice at White Rose. Old ice, which is ice that has survived one or more summer melt seasons, appears only very rarely in the region. It is denser, and hence harder than regular sea ice because it has been re-frozen many times and much of its brine has leached out. Old ice is difficult to detect within the ice pack, but in practical terms, poses the same threat to vessels as growler- and bergy bit-sized iceberg fragments.

Table 2.5–1 Characterization of Sea Ice by Type, Thickness and Age

Description	Thickness (cm)	Age
New ice	10	Earliest stage of development
Grey ice	10-15	Early season first year
Grey-white ice	15-30	Mid-season first year
White ice	30-200	First year
Old ice	-	Second and multi-year ice
Source: AES, MANICE April 1994.		

A typical annual cycle of change in the composition and overall concentration of sea ice off Newfoundland is shown in Figure 2.5-2.

Figure 2.5–2 Average Composition and Total Concentration of Sea Ice, Canadian East Coast



2.5.2.2 Spatial Distribution

The White Rose site lies close to the extreme southern limit of the regional ice pack. In this area, relatively high water temperatures dissipate the last remnants of ice that have drifted south from original ice growth areas in Baffin Bay, Davis Strait and the Labrador Sea.

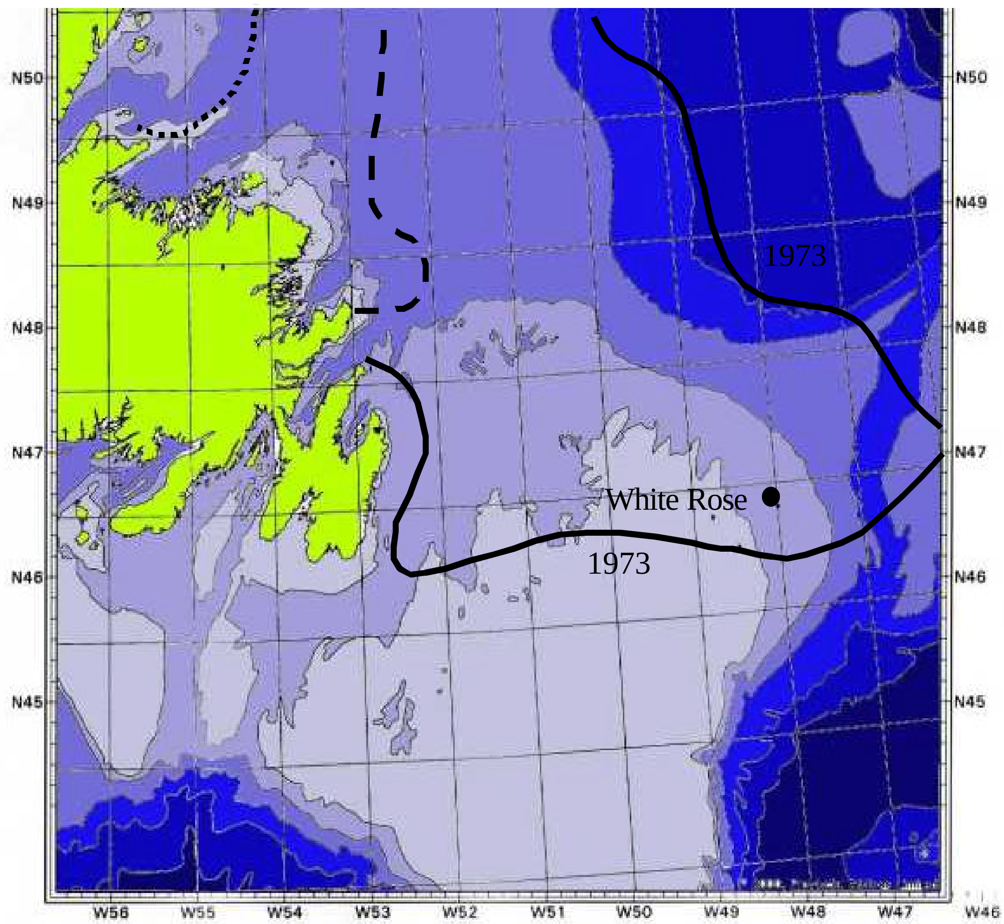
The annual regional ice cycle begins in September with the growth of new ice in Northwest Baffin Bay. Beginning in October, a combination of growth and predominantly southward drift, driven by the prevailing northerly winds and the strong, cold Baffin Current, advances the ice southward. By December, the leading edge of the advancing ice pack lies off northern Labrador. Simple modelling estimates (Marko et al. 1994b) suggest that in April, 60 to 80 percent of the ice south of 55°N has grown in areas north of 60°N.

In typical years, the ice edge reaches the northern tip of Newfoundland in early January and the Grand Banks in mid-February (Navoc 1986). The pack ice off Newfoundland generally reaches annual peak coverage in March but can remain at high levels through May. Thicker first-year or white ice becomes the dominant ice form in areas off Newfoundland beginning in March, just before water temperatures rise above the freezing level (Figure 2.5-2).

Subsequently, the ice pack retreats rapidly northward, with substantial ice concentrations confined to north of Labrador by the end of July. Occasionally, first-year ice remnants remain at the end of the summer season off the east coast of Baffin Island, near 70°N. These remnants, together with late discharges of first-year and older ice from Lancaster, Jones and Smith sounds, are the source of the old ice that can appear off Labrador the following ice season (Markham 1980).

Seasonal ice coverage in Newfoundland waters is shown by plots of extreme and median positions of the ice edge midway through each of the months of January through May, in Figures 2.5-3 to 2.5-7, respectively. The minimum, or least-advanced, ice-edge positions are not shown because, in all months, the region was ice-free in at least one year of the study period. The median ice edge position shows the ice edge for a hypothetically typical year; half the time the ice is farther south and half the time farther north than the median line. The median ice edge is greater for the 1988 to 1995 data set than for the 1963 to 1987 data set. The maximum ice positions shown are composites of the most advanced ice-edge positions recorded in each compass direction over the period of record. The years associated with the individual sections of these maximum ice-edge boundaries are indicated.

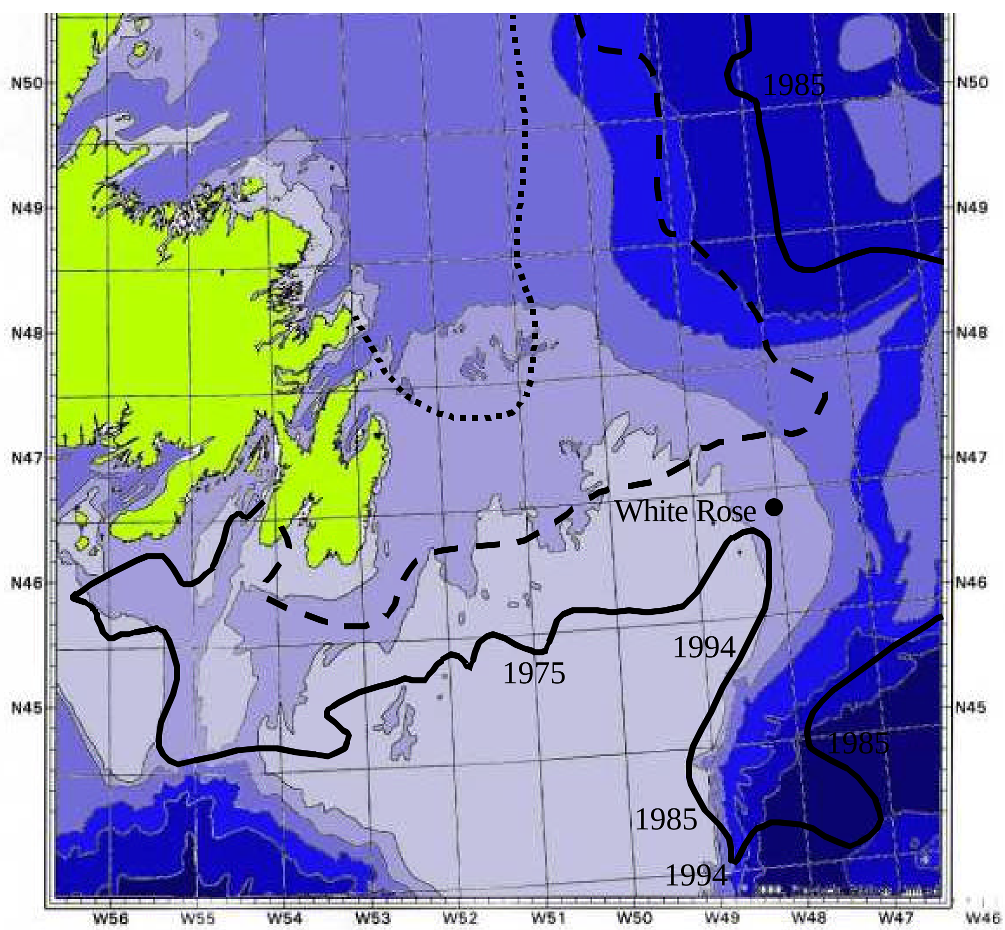
Figure 2.5–3 Median and Maximum Sea Ice Limits for the Week of January 14, 1959 to 1999



– – – –	Median (1988 – 1995)
....	Median (1963 – 1987)
┼────┼	Maximum (1959 – 1999) with year of occurrence

Source: Petro-Canada (1995) updated by AES Composite Ice Charts (1960 to 1999)

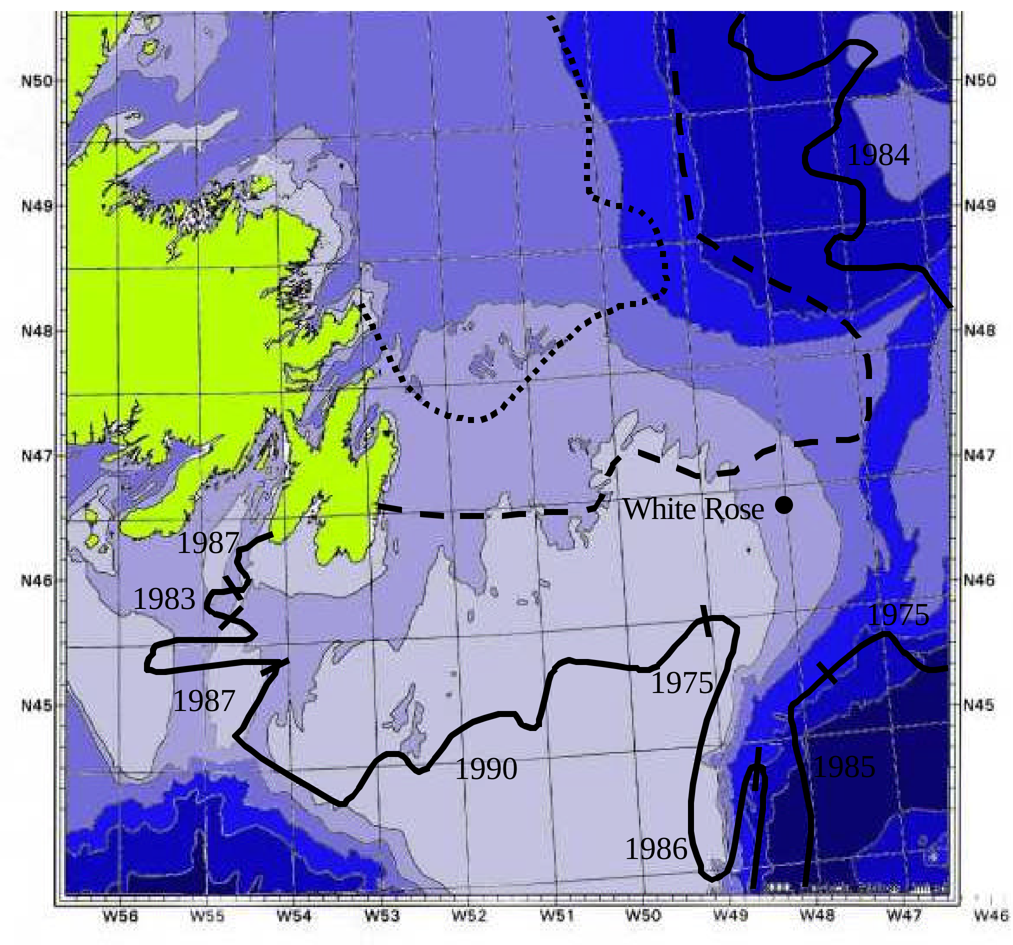
Figure 2.5–4 Median and Maximum Sea Ice Limits for the Week of February 19, 1959 to 1999



— — — —	Median (1988 – 1995)
....	Median (1963 – 1987)
┼──┼	Maximum (1959 – 1999) with year of occurrence

Source: Petro-Canada (1995) updated by AES Composite Ice Charts (1960 to 1999)

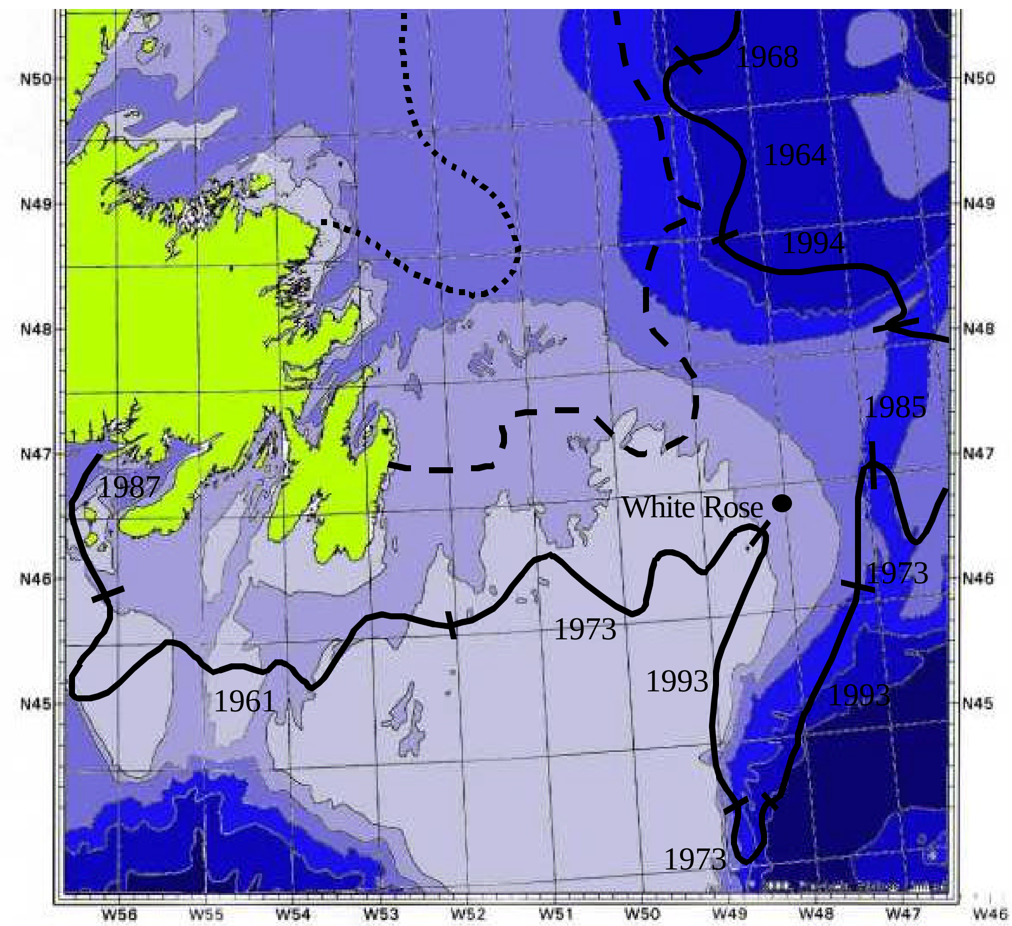
Figure 2.5–5 Median and Maximum Sea Ice Limits for the Week of March 19, 1959 to 1999



– – – –	Median (1988 – 1995)
....	Median (1963 – 1987)
┼──────┼	Maximum (1959 – 1999) with year of occurrence

Source: Petro-Canada (1995) updated by AES Composite Ice Charts (1960 to 1999)

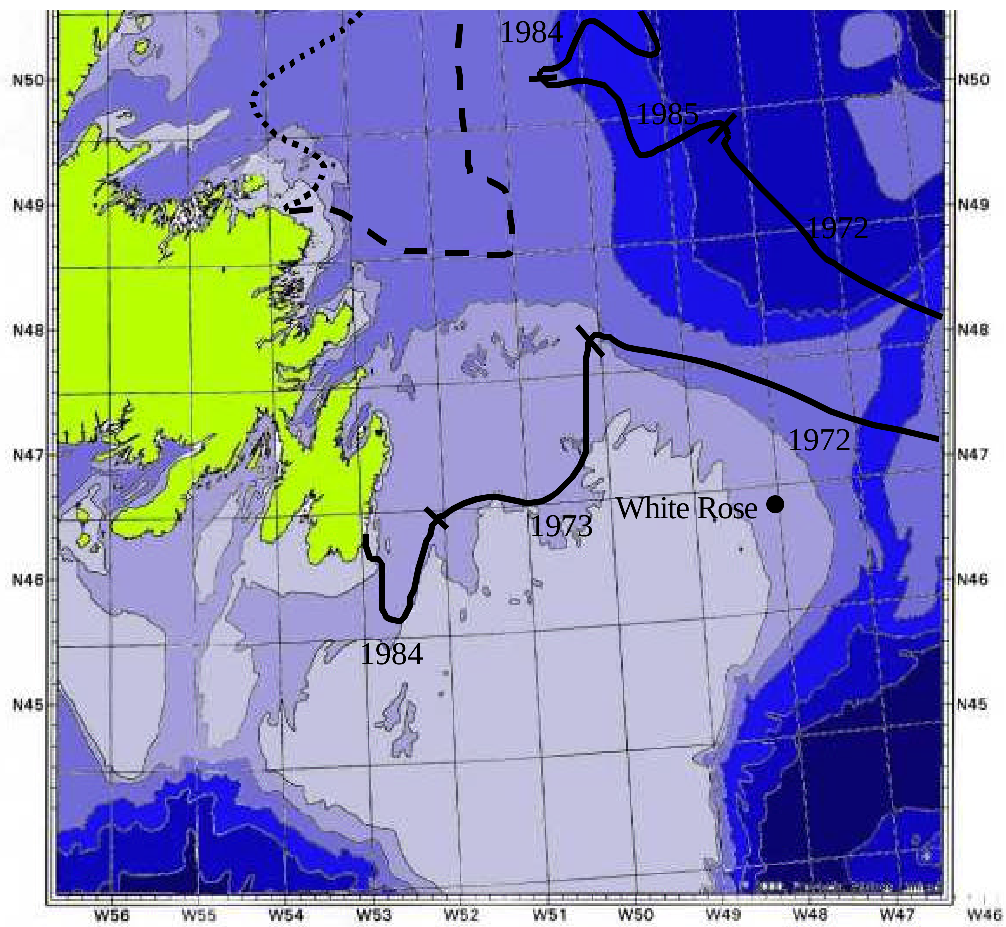
Figure 2.5–6 Median and Maximum Sea Ice Limits for the Week of April 16, 1959 to 1999



— — — —	Median (1988 – 1995)
....	Median (1963 – 1987)
┼──────┼	Maximum (1959 – 1999) with year of occurrence

Source: Petro-Canada (1995) updated by AES Composite Ice Charts (1960 to 1999)

Figure 2.5–7 Median and Maximum Sea Ice Limits for the Week of May 14, 1959 to 1999



— — — —	Median (1988 – 1995)
....	Median (1963 – 1987)
┼──────┼	Maximum (1959 – 1999) with year of occurrence

Source: Petro-Canada (1995) updated by AES Composite Ice Charts (1960 to 1999)

Two different median ice-edge boundaries are shown in Figures 2.5-3 to 2.5-7:

- one boundary identifies the 0.5° latitude x 1.0° longitude grid cells where sea ice had a 50 percent probability of occurring based on ice charts for the period 1963 to 1987 (Seaconsult 1988); and
- the second median ice edge was obtained by applying identical procedures to ice charts from 1988 to 1995.

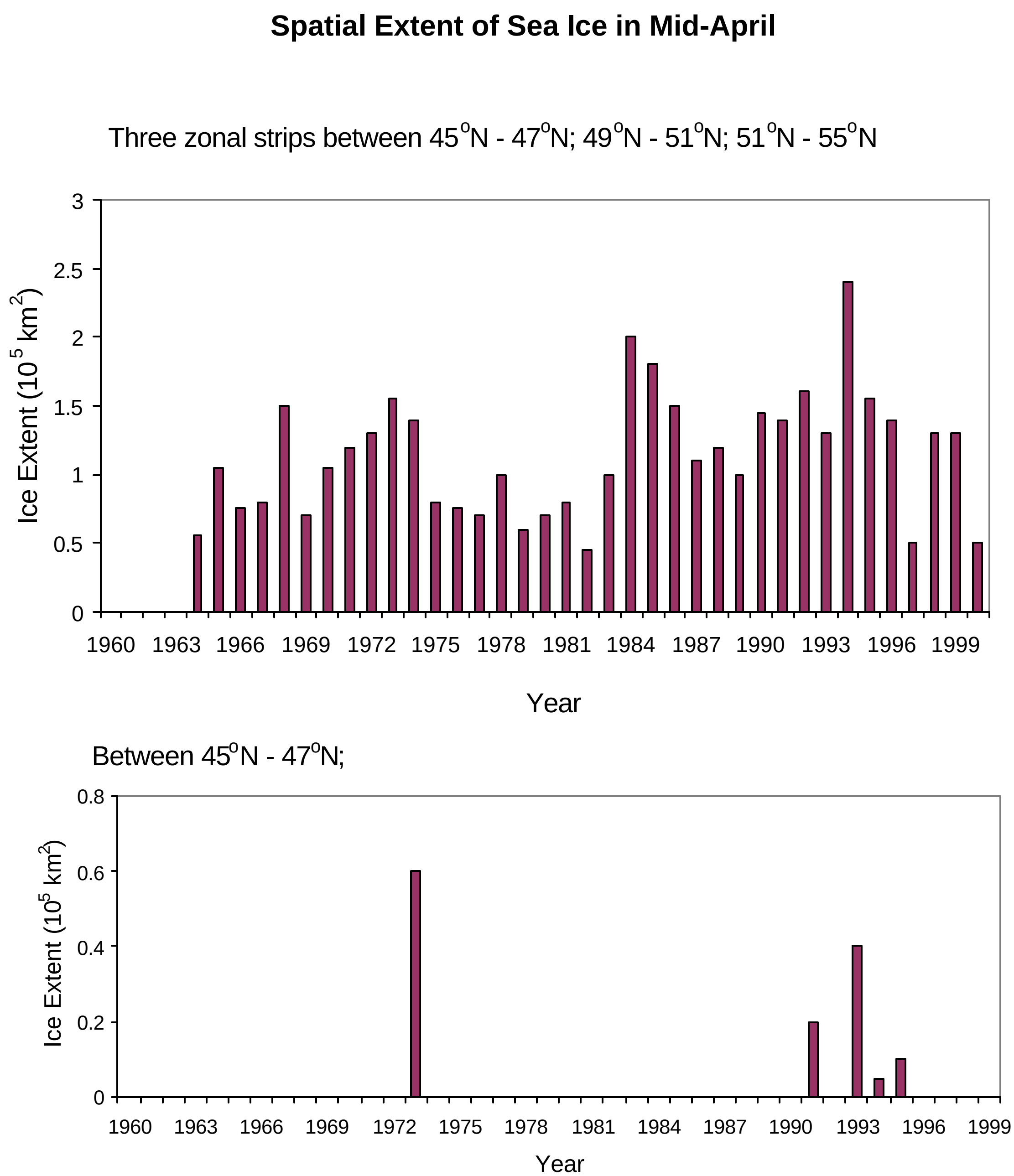
The 1988 to 1995 data were included to illustrate the possibility of very substantial changes in ice conditions, generally attributed to variations in climate. The substantially more southerly and easterly positions of the post-1987 monthly median ice edges reflect the more extensive ice coverage that has been observed in Eastern Canadian waters since 1983. This coverage, similar to that observed during the years 1910 to 1930, is among the most extensive for the 20th century (Miles 1974).

The monthly maximum sea ice extent in relation to the bathymetric contours that define the continental shelf are also indicated in Figures 2.5-3 to 2.5-7. The effects on sea ice distribution caused by the faster moving Labrador Current to the east of the Grand Banks and through the near-shore Avalon Channel can be clearly seen in these figures.

Ice conditions in the preceding four decades are shown in Figure 2.5-8. The plot shows annual mid-April ice extents for 45°N to 47°N (this includes the White Rose site). These data show that the mean ice coverage has increased by over 40 percent since 1983 relative to the earlier 1963 to 1982 period and that the probability of ice occurring in the White Rose area at this time of year is also greater for the more recent time period. The reason for this is unknown at this time, but may be related to more global changes in climate. It is noteworthy that there has been no occurrence of sea ice in the White Rose area since 1995.

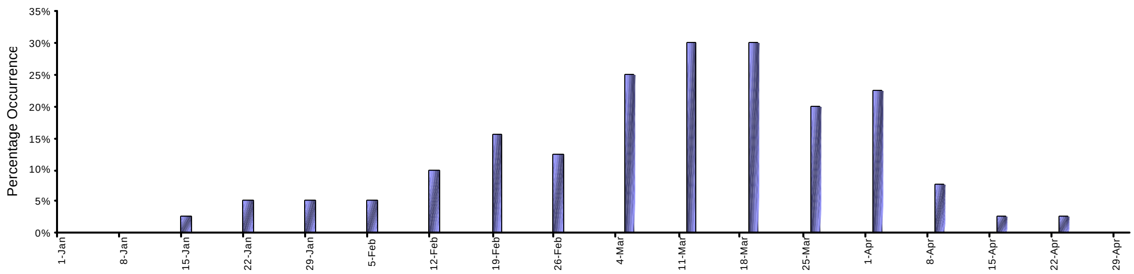
The annual timings of all 1960 to 1999 ice incursions within 15 km of White Rose (based on CIS weekly ice charts) are shown on Figure 2.5-9. These data show the onset (roughly in 1983) of higher incursion together with the ice incursions centred broadly in mid-March. This is when ice coverage around Newfoundland usually peaks (see Figures 2.5-3 to 2.5-7). The White Rose location has experienced sea ice incursions in nearly half of the data years. The duration of the incursions varies from a low of one week to a high of 11 weeks. Of the 20 years that ice was present, the average duration was four weeks.

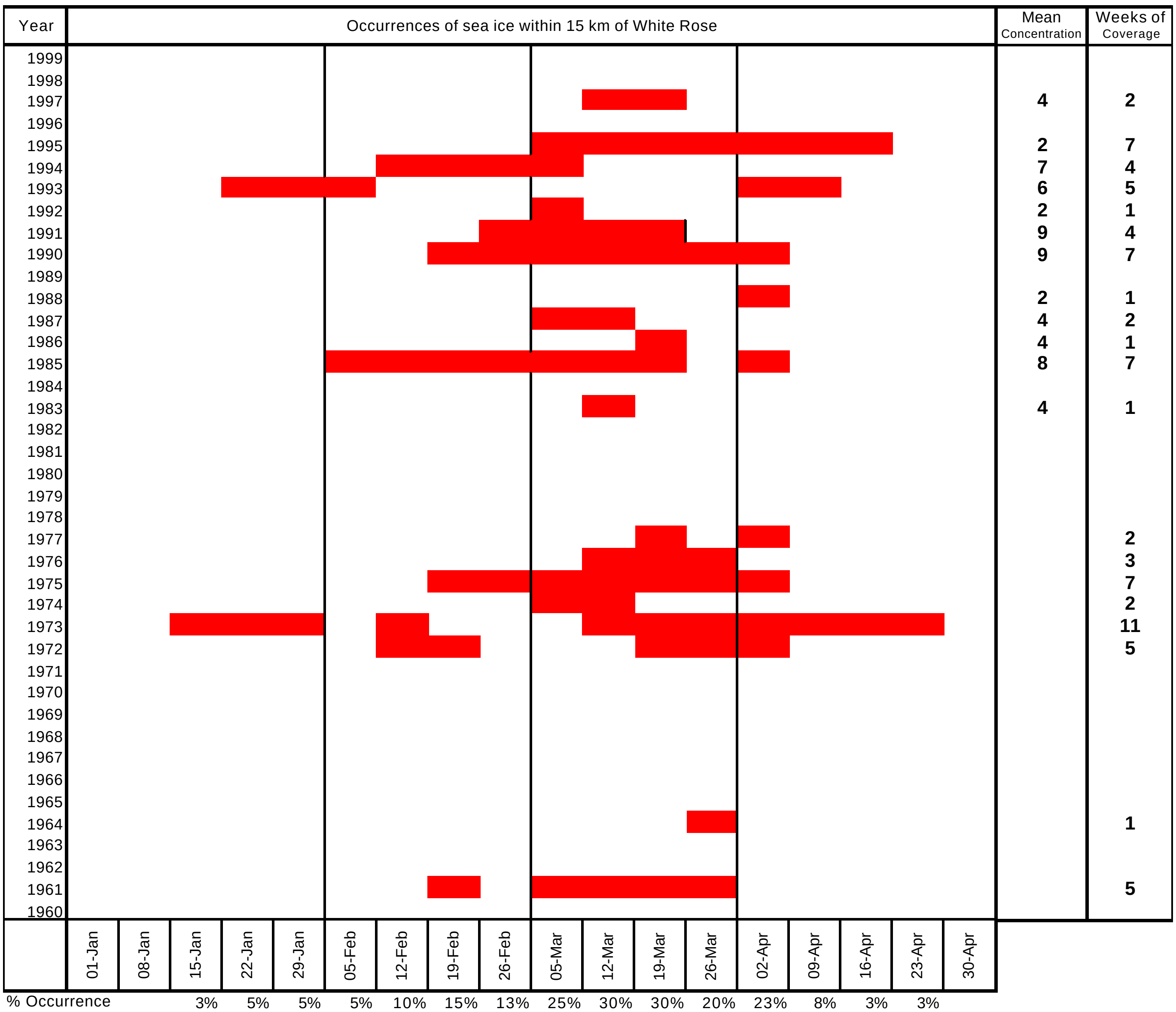
Figure 2.5–8 Spatial Extent of Sea Ice in Mid-April



Source: CIS composite Ice Charts (1963 - 1999)

Figure 2.5–9 Weekly Incursions of Sea Ice within 15 km of White Rose





Source: CIS Ice Charts 1960 to 1999

2.5.2.3 Sea Ice Movement

While the position of White Rose is at the extreme southern limit of the regional ice pack, it does lie within the path of the ice tongue that is formed by the loose pack being swept around the Grand Banks by the offshore branch of the Labrador Current. Mean sea ice velocities as derived from satellite imagery are shown in Figure 2.5-10 and clearly illustrates the faster moving ice associated with the tongue. The accuracies of the individual vectors are lowest in the Grand Banks region. However, as expected, the fields of motion shown are very similar to those of the regional surface currents.

The principal circulation features are:

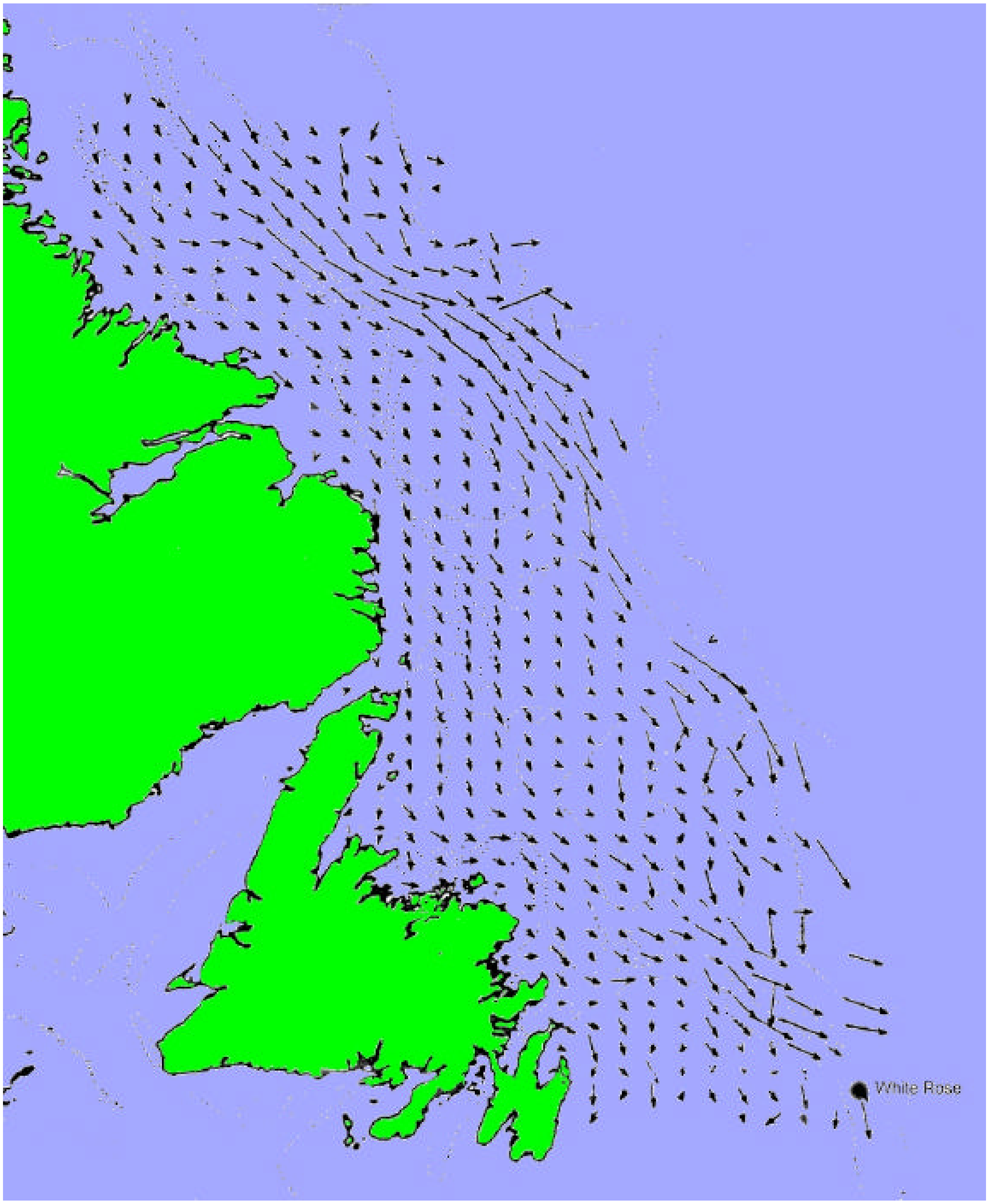
- strong easterly and southerly movements associated with the outer branch of the Labrador Current on the northern and eastern slopes of the Grand Banks;
- a weaker southerly drift, evident in the Avalon Channel, associated with a continuation of the inner branch of the Labrador Current;
- over the body of the Grand Banks, a mean flow that is weaker and less definitive in direction; and
- extreme variability of velocities of ice and surface currents. Their standard deviations are comparable to or larger than their corresponding long-term temporal averages.

Drift speed and direction distribution are shown in Figure 2.5-11 (derived by Seaconsult (1988) from satellite-tracked, ice-mounted, drift buoy data between 1984 and 1987). The original buoy deployments, (Fissel et al. 1985) on ice floes at approximately 49°N, just north of the northern edge of the Grand Banks, were more or less immediately swept up in the Labrador Current. They then followed trajectories of the strong currents that follow the slope regions at the edge of the Grand Banks. As a consequence, the indicated velocities should be representative of sea ice movement at the White Rose site.

2.5.2.4 Concentrations

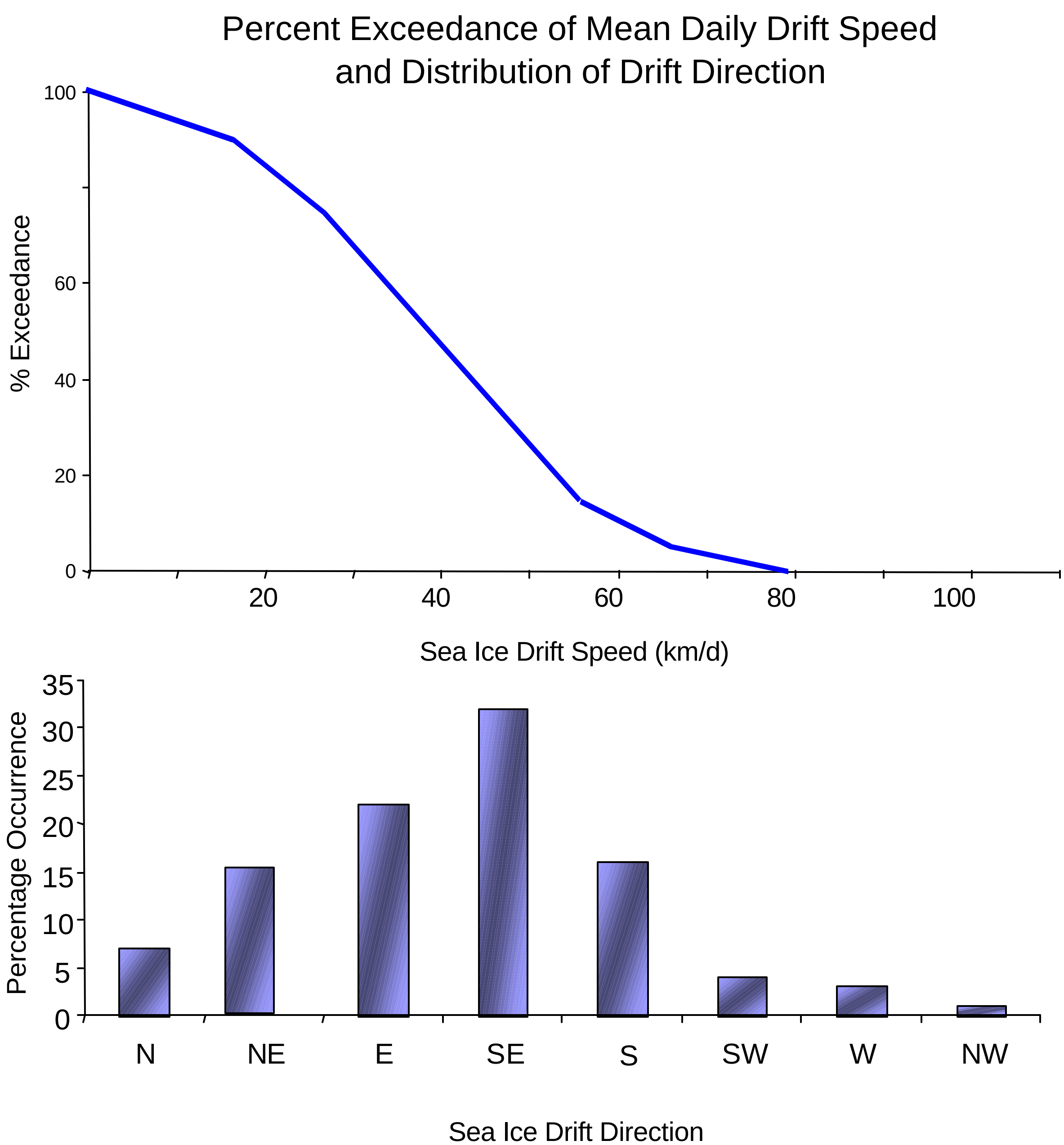
Mean sea ice concentrations for the Grand Banks south of 49°N are fairly consistent at approximately 6/10ths coverage. Ice concentrations of greater than 5/10ths are evident by early February and continue through to mid-April, after which they slowly decrease to 2/10ths coverage (Figure 2.5-12).

Figure 2.5–10 Mean Sea Ice Velocity Derived from Satellite Imagery



Source: Peterson 1990

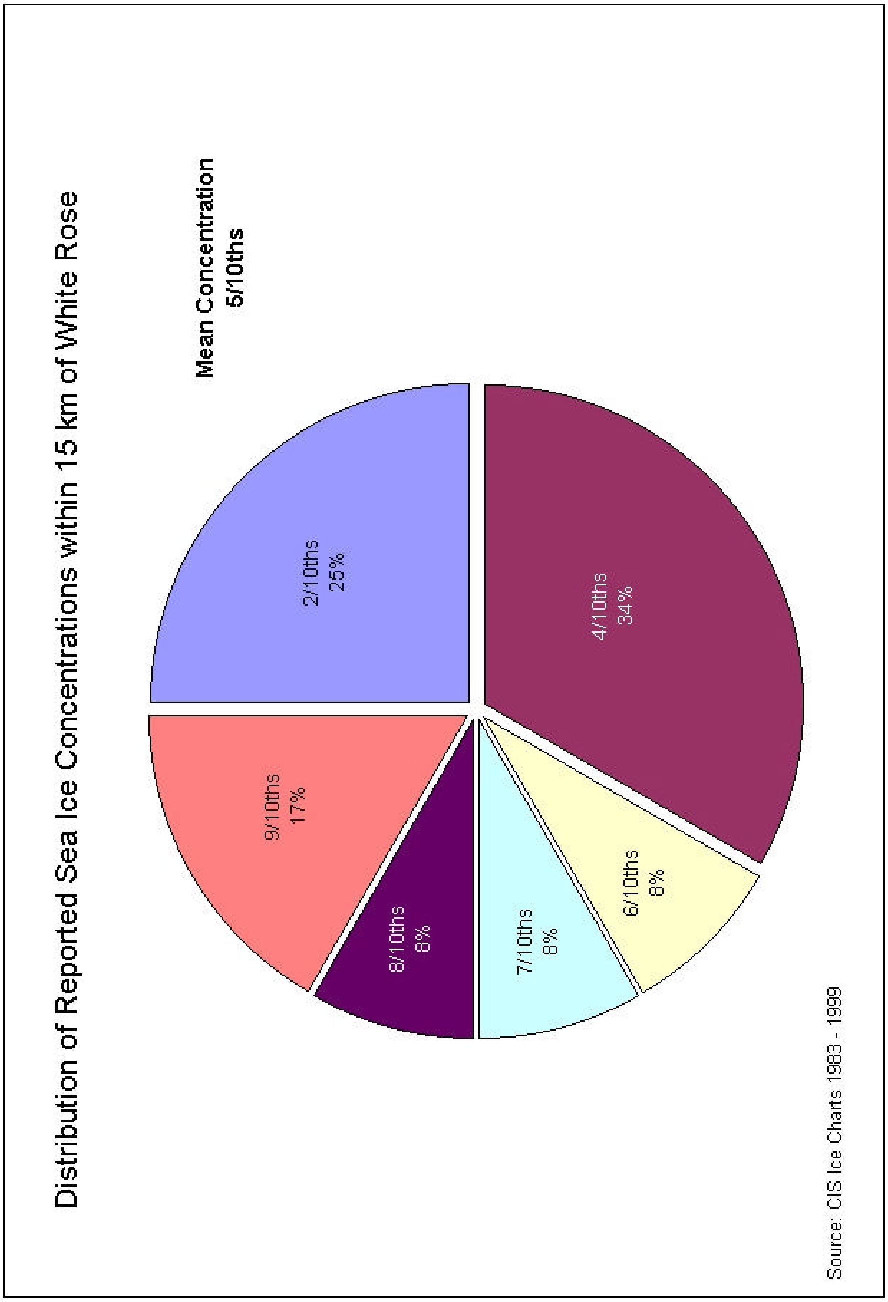
Figure 2.5–11 Percent Exceedance of Mean Daily Drift Speed and Distribution of Drift Direction



Data: February through April 1985

Source: Fissel et al. (1985)

Figure 2.5–12 Distribution of Sea Ice Concentrations within 15 km of White Rose



White Rose can be affected by the seasonal ice tongue (created when sea ice is swept around the edge of the Grand Banks by the Labrador Current) because it is located between the 100 and 200 m depth contours. Ice concentrations in the tongue are usually at the lower end of ice coverage – 2/10ths to 4/10ths. However, in extreme years, the White Rose area has experienced short periods of 9/10ths coverage. Analysis of CIS ice charts for the years 1979 to 1999 shows that, for the years when ice was present, mean overall ice concentration within 15 km of White Rose was 5/10ths.

2.5.2.5 Floe Size

The horizontal dimensions of individual ice floes are influenced by:

- ice history;
- concentration;
- thickness;
- water temperature;
- sea state; and
- proximity to land.

In Newfoundland waters, a distinction is made between the size of floes located within roughly 100 km of the coastline and those in areas north and south of the 49°N boundary of the Grand Banks. Large floes occur more often in the inshore area because of:

- physical confinement;
- colder air;
- colder water temperatures;
- damping of wave amplitudes by seaward ice.

In the two offshore areas, floe sizes are smaller south of 49°N because of:

- melting;
- fracturing;
- higher water temperatures; and
- sea states.

In both offshore regimes, floe size decreases from west to east because of progressive decreases in wave amplitudes propagating into the pack ice from the open ocean.

AES composite ice chart data for 1964 to 1987 indicate that, within 50 km of White Rose, floes larger than 100 m are present only 10 percent of the time. Estimates made in several earlier studies (Blenkarn and Knapp 1969; Nolte and Trethart 1971; LeDrew and Culshaw 1977; Dobrocky Seatech 1985) indicate that mean floe diameters in offshore areas south of 49°N are less than 30 m. Only a few floes with diameters larger than 60 m were observed.

A northwest-to-southeast size gradient also was identified (Dobrocky Seatech 1985). Mean and maximum floe diameters decreased from 8 m and 37 m, respectively, at 49°N, 51°W to 1 m and 3 m in the vicinity of White Rose (Seaconsult 1988). Mean and maximum diameters may exceed these values by an order of magnitude or more (Seaconsult 1988) when the ice extent is close to its seasonal maximum in years of exceptionally severe ice conditions.

There is evidence that many of the larger floes recorded in the cited studies were observed on coarse resolution (1 km) satellite images. It is likely that these floes are conglomerates of smaller floes bound at their peripheries by newly-grown thinner ice (Petro-Canada 1995).

2.5.2.6 Thickness

Physical growth of sea ice on the Grand Banks occurs mainly south of the main pack edge, and in leads and open patches within the pack. This is 'new ice' (Table 2.5-1) that is usually formed only in calm wind conditions. It tends to be short-lived as a distinct entity. Wave action tends to disperse new ice which melts in later warmer periods. Most often it is incorporated into adjacent floes and deformed ice structures.

Most of the sea ice found on the Grand Banks is formed in upstream areas and increases in thickness during subsequent southward drift during the ice season. Most of the ice coverage within 15 km of White Rose ranges from 30 to 100 cm in thickness. Detailed average thickness in undeformed sea ice near White Rose is shown in Figure 2.5-13. These data were derived subjectively from CIS ice chart data for periods of ice coverage 1985 to 1999 that exceeded four weeks in duration.

Ice substantially thicker than 100 cm is absent on the Grand Banks as a whole (Figure 2.5-14), and average thicknesses below 50 cm are the most common, which agrees with most field observations.

Figure 2.5–13 Average Ice Thicknesses at White Rose

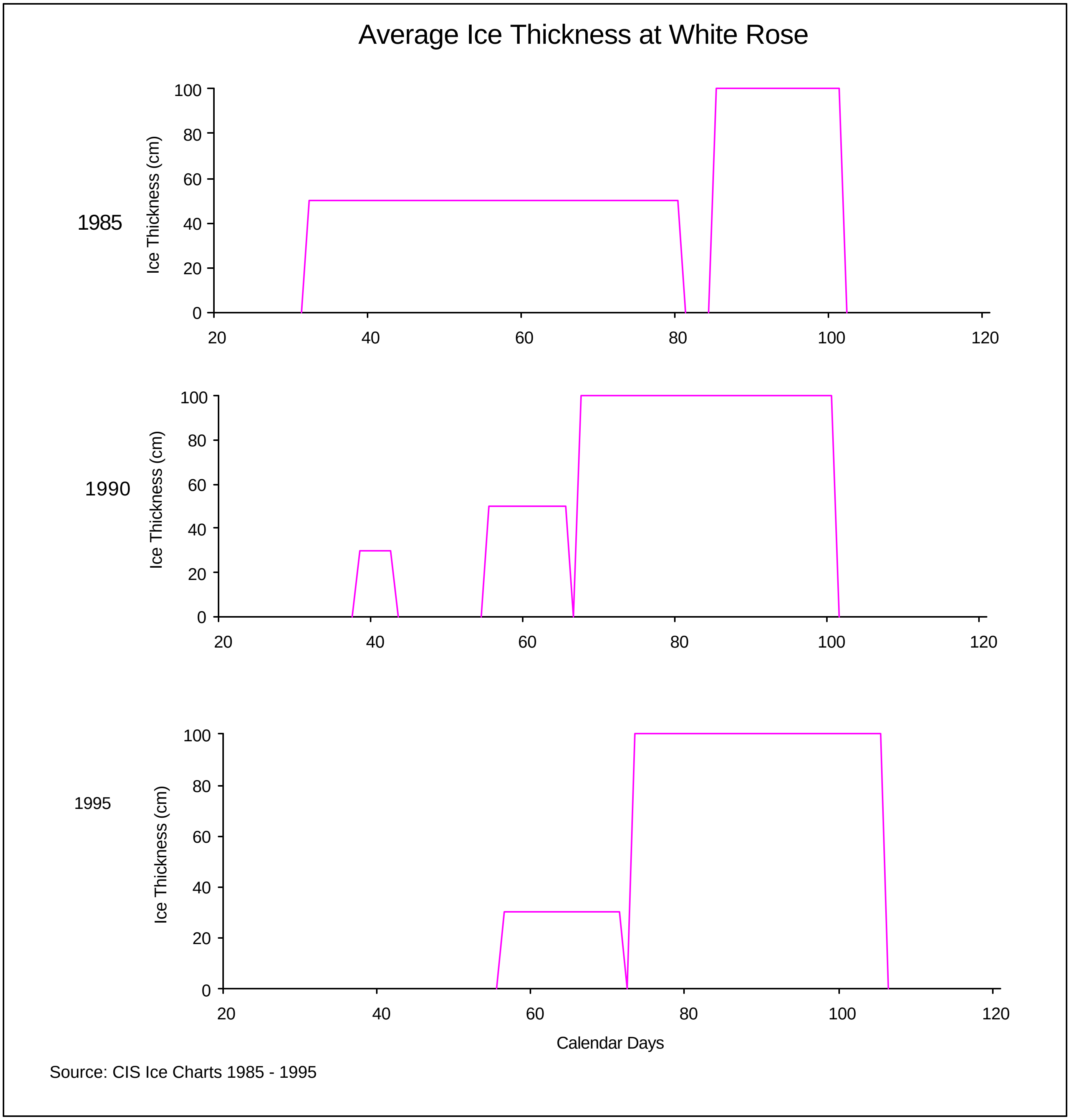
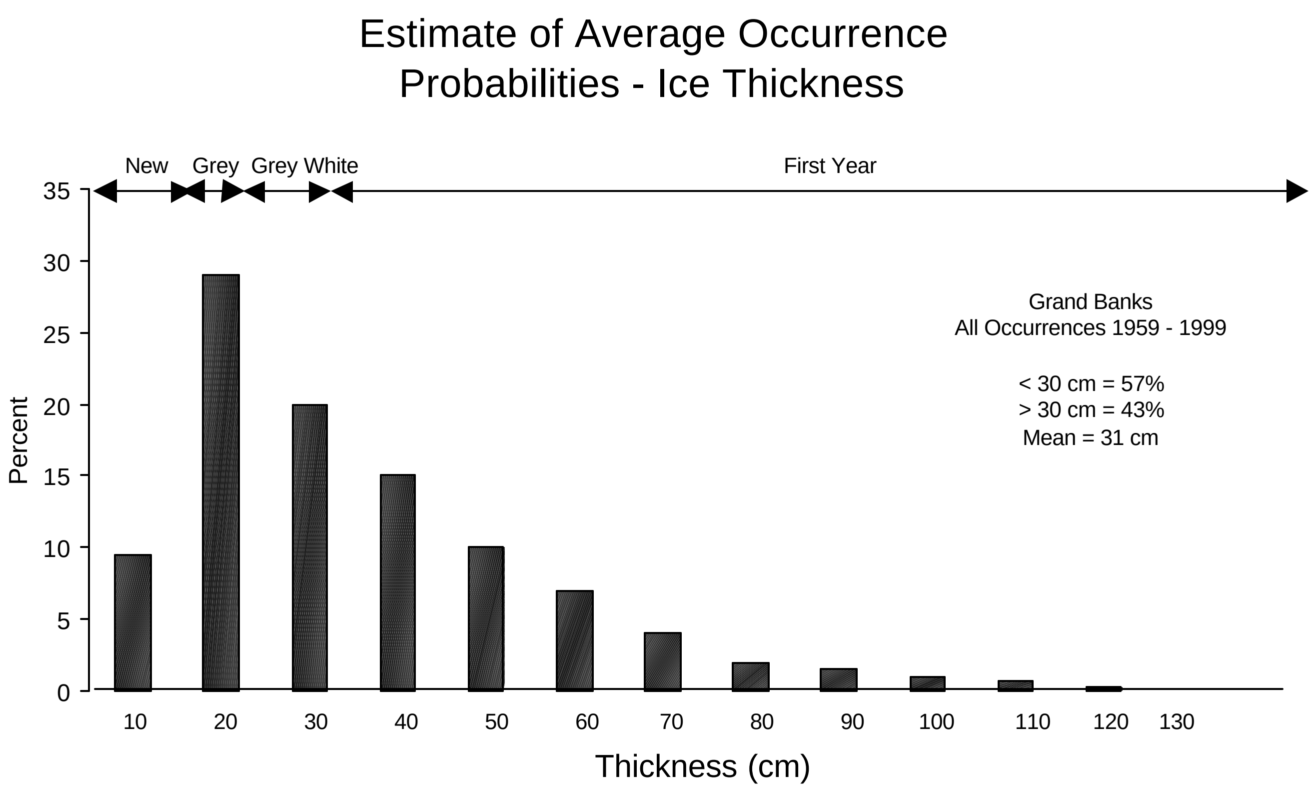


Figure 2.5–14 Estimate of Average Occurrence Probabilities - Ice Thickness



Source: Seaconsult (1988)

2.5.2.7 Deformation

The maximum thickness of undeformed sea ice is largely determined by:

- heat flow from the ocean at the under-surface of the ice; and
- rate of heat loss at the ice surface.

Ice on the northern Grand Banks that is thicker than approximately 50 cm has drifted from colder, more northern areas, as noted earlier, or is present through ice deformation.

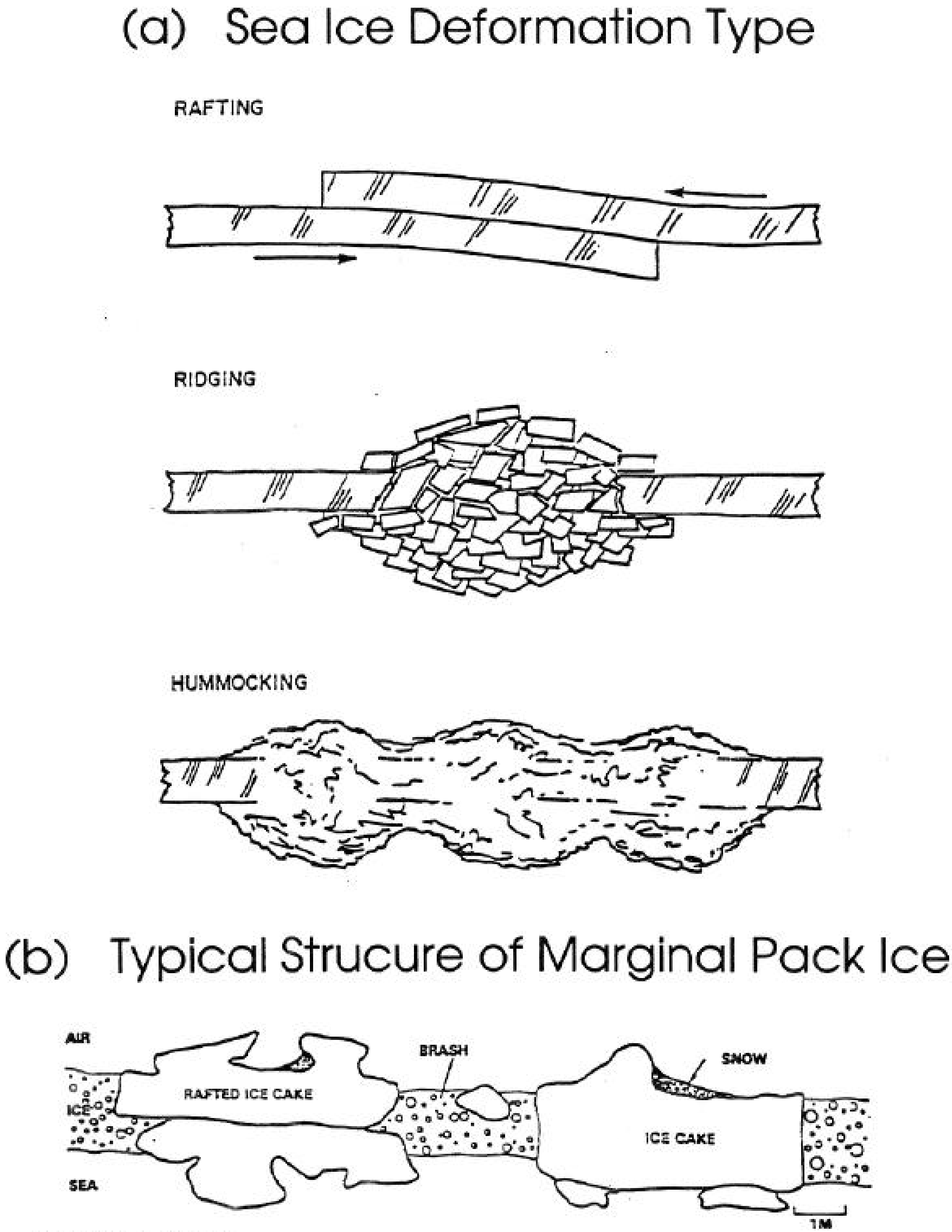
Most types of sea ice deformation occur in highly concentrated (approximately 10/10ths) pack ice, typically near land. Deformations are classified as rafting, ridging or hummocking (Figure 2.5-15). Rafting occurs when one sheet of ice overrides an adjacent sheet. Ridging is produced by repeated local failures at a common boundary between two sections of relatively undeformed ice. The third category, hummocking, refers to a much wider spatial distribution of randomly scattered broken and upturned ice blocks.

Quantitative data on deformed ice are usually confined to ridge-type deformations because they can be easily characterized by:

- frequency (number of ridges/km);
- length;
- width; and
- maximum top-to-bottom thickness (sail height plus keel depth).

Few quantitative data are available for the Grand Banks region, in part because linear ridge formations of the type commonly observed in Arctic areas are relatively rare here. Instead, the deformed pack ice consists of fields of confused jumbles of uplifted and broken floes (Petro-Canada 1995) (Figure 2.5-15). Observation indicates that maximum sail heights, corresponding to local peak heights in such fields, are approximately 2 m (Dobrocky Seatech 1985). Nolte and Trethart (1971) calculated average ridge heights of approximately 1 m. These estimates are reasonably consistent with airborne electromagnetic sensor measurements in Newfoundland areas farther inshore (Prinsenberg et al. 1993).

Figure 2.5–15 Sea Ice Deformation Types



Source: Perto-Canada (1995)

Ridge thicknesses for the Grand Banks have also been estimated from data gathered off southern Labrador during February and early March and extrapolated to the Grand Banks and White Rose region (Seaconsult 1988). These estimates indicate that ridges or rubble fields with sails as large as 3.5 m could form on the Grand Banks (Bradford 1972; Nordco 1977). However, these estimates are offset by the fact that the farther south the ice deformations occur, the faster the rafted and upturned floes, as well as the thin, binding ice between the floes, will melt. As melting occurs, structural fragility and ice porosity increase, thereby reducing the operational hazards of any ridge or rubble field fragments that survive to well below those associated with smaller pieces of old or glacial ice.

2.5.3 Icebergs

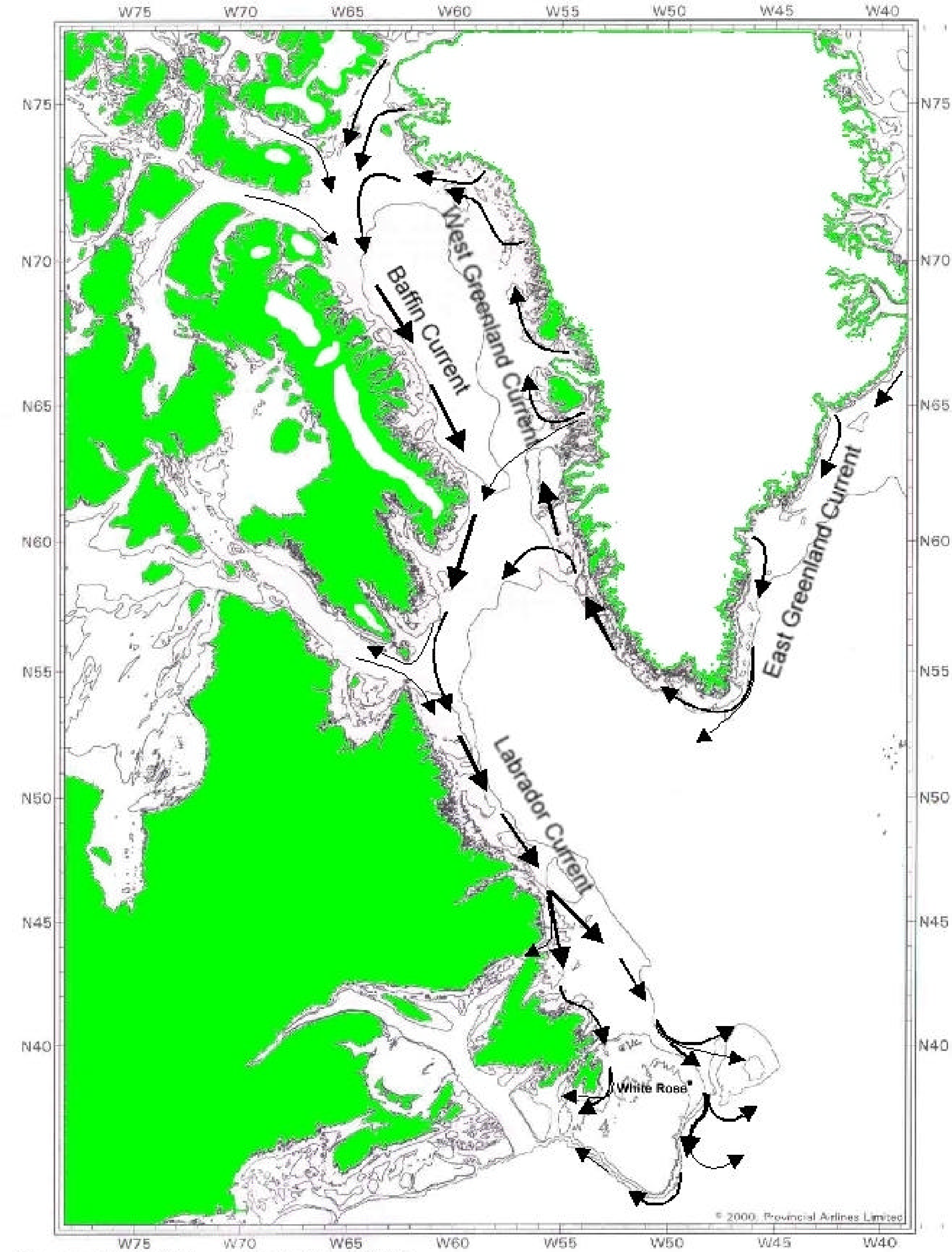
2.5.3.1 Origins and Controlling Factors

Glacial ice is formed from the accumulation of snow, which gradually changes form as it is compressed into a solid mass of large granular ice. This process produces a structure quite different from pack ice. The principal origins of the icebergs that reach the White Rose location are the 100 tidewater glaciers of West Greenland. Between 10,000 and 15,000 icebergs are calved each year, primarily from 20 major glaciers between the Jacobshaven and Humboldt glaciers. These glaciers account for 85 percent of the icebergs that reach the Grand Banks: 10 percent come from the East Greenland glaciers and the glaciers and ice shelves of Ellesmere Island account for the other 10 percent and 5 percent, respectively.

The basic regional circulation pattern shown in Figure 2.5-16 reflects the predominant strong cyclonic ocean currents centred on the continental slopes. Most icebergs reaching Newfoundland initially move northward, taking a year or so to reach northwestern Baffin Bay. In the interim, the icebergs melt, fracture and subdivide, reducing their size, on average, by a factor of about two. Many icebergs never reach northwestern Baffin Bay because of long-term or repeated groundings accompanied by melting in shallow waters off West Greenland. Similar iceberg losses occur in waters adjacent to Baffin Island and Labrador during the warm, sea ice-free months.

In fact, there is considerable evidence (Marko et al. 1994a) that most icebergs reaching Newfoundland each spring and summer have drifted southward across 75°N between September and November of the previous year. This timing allows these icebergs to avoid substantial depletion during subsequent winter drift past the Baffin Island and Labrador coastlines.

Figure 2.5–16 Iceberg Circulation



Source: (IIP 1993, updated PAL 1995)

Deterioration of icebergs during subsequent southward drift determines seasonal iceberg severities off Newfoundland. The number of icebergs that survive to reach the Grand Banks each spring has been shown to have a direct relationship to the pack ice extent off Labrador in the winter and early spring (Marko et al. 1994a). In other words, when the pack ice covers the core of the Labrador Current, iceberg counts for the Grand Banks increase markedly per unit increase in pack ice cover.

According to the IIP, the number of icebergs reaching the Grand Banks each year varied from a low of 0 in 1966 to a high of 2,202 in 1984, with the average over the last 10 years being approximately 900 icebergs (Figure 2.5-17). Of these, only a small proportion will pass through the White Rose area. Over the last 10 years, the average yearly number of icebergs sighted in the 1° grid containing White Rose has been 47.

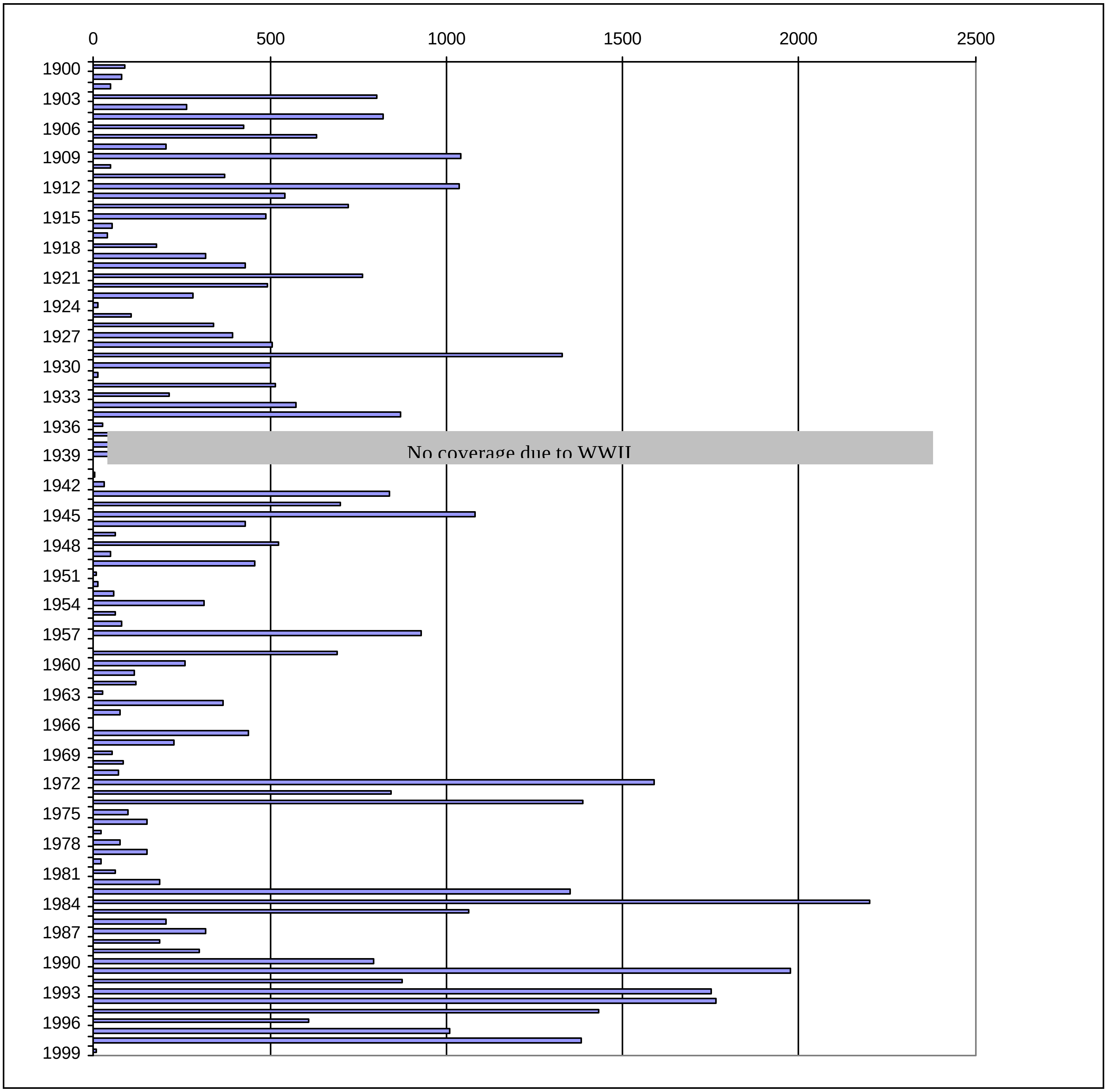
2.5.3.2 Variations in Local and Regional Iceberg Numbers

The number of icebergs crossing any given latitude off Eastern Canada varies considerably both annually (Figure 2.5-17) and monthly. There has been much discussion on the apparent increase in icebergs south of 48°N over the past decade. Prior to 1999, the long-term record indicates a trend towards a larger number. However, there was a severe drop in icebergs south of 48°N in the 1999 iceberg season. This low number has been attributed to a combination of very light sea ice coverage and higher than normal water temperatures on the Grand Banks.

This situation is not unique; within the past century there have been several periods where the record indicates fewer than a dozen icebergs. In fact, there are several consecutive seasons with very low numbers. The record indicates that these periods are usually followed by a return to the "normal". It is much too soon to speculate on whether these low numbers from 1999 are the beginning of a trend or just part of the variability in the annual count.

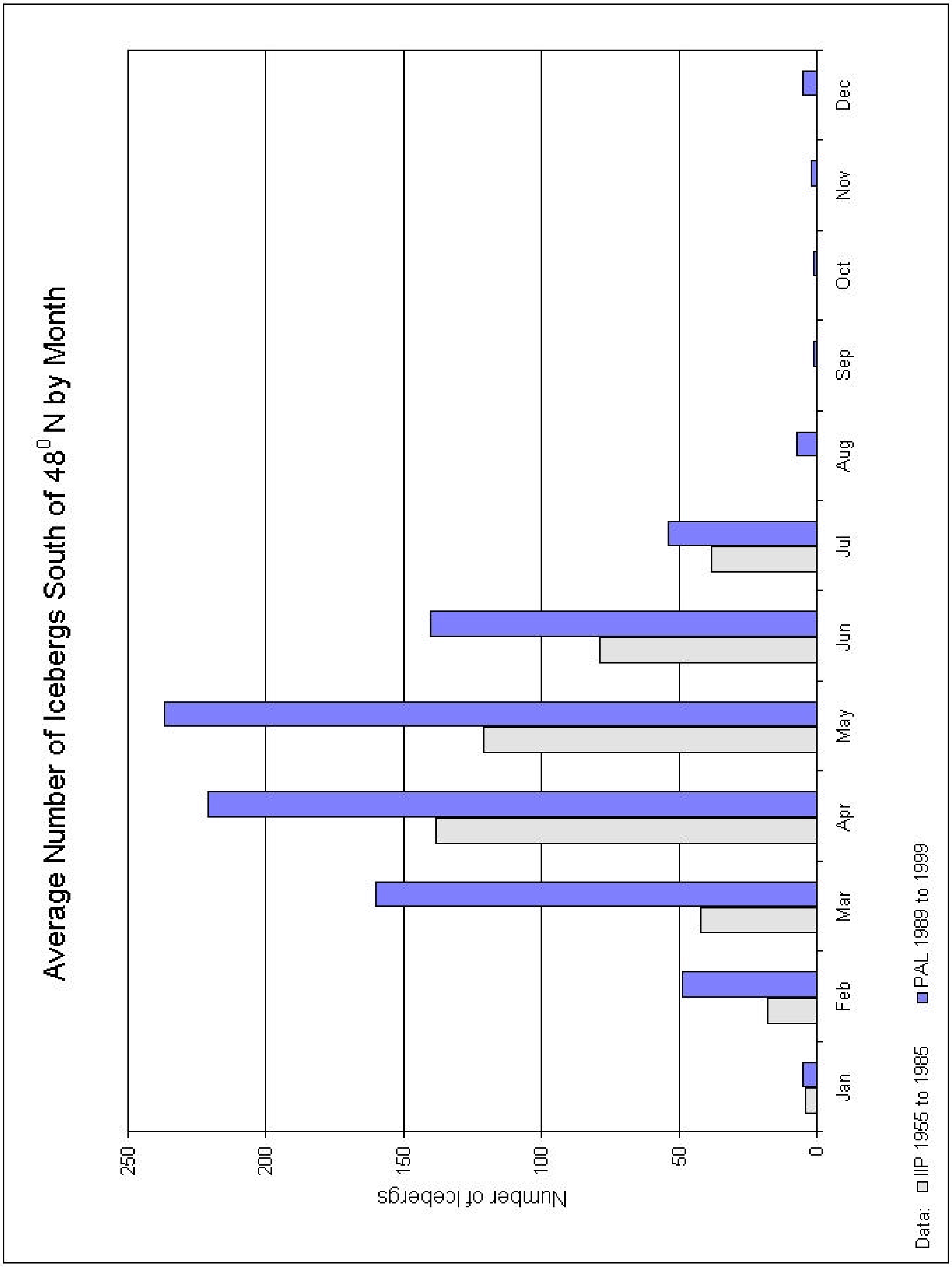
At 48°N, on the approaches to the White Rose site, long-term averages of data compiled by PAL from 1989 to 1999 (Figure 2.5-18) show that regardless of how many icebergs arrive, the number peaks in May but is at high levels from March to June. A comparison with iceberg sighting data from IIP for the period 1955 to 1985 is plotted alongside the PAL data. As expected, the average number of icebergs sighted is lower because of smaller iceberg populations during this period. However, the peak influx still occurs in the April/May period.

Figure 2.5–17 IIP Annual Count of Icebergs Crossing of 48° N



Source: International Ice Patrol. 1999.

Figure 2.5–18 Average Number of Icebergs South of 48° N by Month



Note that while the major iceberg flux falls into the March to June period, iceberg sightings on the approaches to White Rose have been made at least once in each month - January through December - and in 1993, approximately 20 percent of the icebergs crossed 48°N in February.

Variations in the timing of iceberg influxes reflect annual differences in southward ice and iceberg drift rates, and wind fields. Winds, and the offshore position and extent of the ice pack, heavily influence iceberg drift rates.

Looking more closely at both the IIP and the PAL data sets yields an interesting observation: the average annual number of icebergs south of 48°N, for the post-1982 period (879 with PAL data and 1,014 with IIP data) is much larger than the mean annual count (297, from IIP data) for the previous 23 years. It has been suggested that the higher iceberg numbers post-1982 have been associated with the initiation of routine use of imaging radar in IIP surveys after 1983 (Seaconsult 1988). As noted previously, this technological advance allowed more efficient and, presumably, more complete surveys. It should be noted that iceberg-free conditions, meaning less than 15 icebergs per year, are constant at an average of approximately 5 percent regardless of the time frame used.

The impact of such an increase in icebergs near the White Rose site is shown by plots of occurrence for different ranges of iceberg numbers observed annually in the 1° grid containing the White Rose site (Figure 2.5-19). Comparisons of data from 1960 to 1982 with the corresponding post-1982 (with the exception of 1999) results show a pronounced shift toward more icebergs per year. The counts suggest that iceberg numbers larger than, alternately 50 to 100 and above-100 icebergs, were approximately twice as probable as in the earlier survey period.

A plot of annual iceberg numbers in other 1° grids between 45°N and 53°N (Figure 2.5-20) using 1989-1999 PAL data shows the regional iceberg distribution. The upper and lower numbers in each rectangle denote, respectively, the maximum and the mean numbers of icebergs observed each year, while the number in the bottom right corner of grids below 50°N shows the number of years in the record that icebergs were observed. The maximum numbers provide a worst-case representation of local annual iceberg severities. However, not all iceberg maximum numbers occurred in the same year. The PAL iceberg database contains over 43,000 visually confirmed iceberg sightings made between 42°N and 55°N. Of these, approximately 23 percent were made south of 48°N.

The maximum number of iceberg sightings (217) for the White Rose grid was observed in 1990. This number, though high, is substantiated by the iceberg tracking records from Petro-Canada's King's Cove A-26 well site.

Figure 2.5–19 Annual Number of Iceberg Sightings in the White Rose 1° Grid

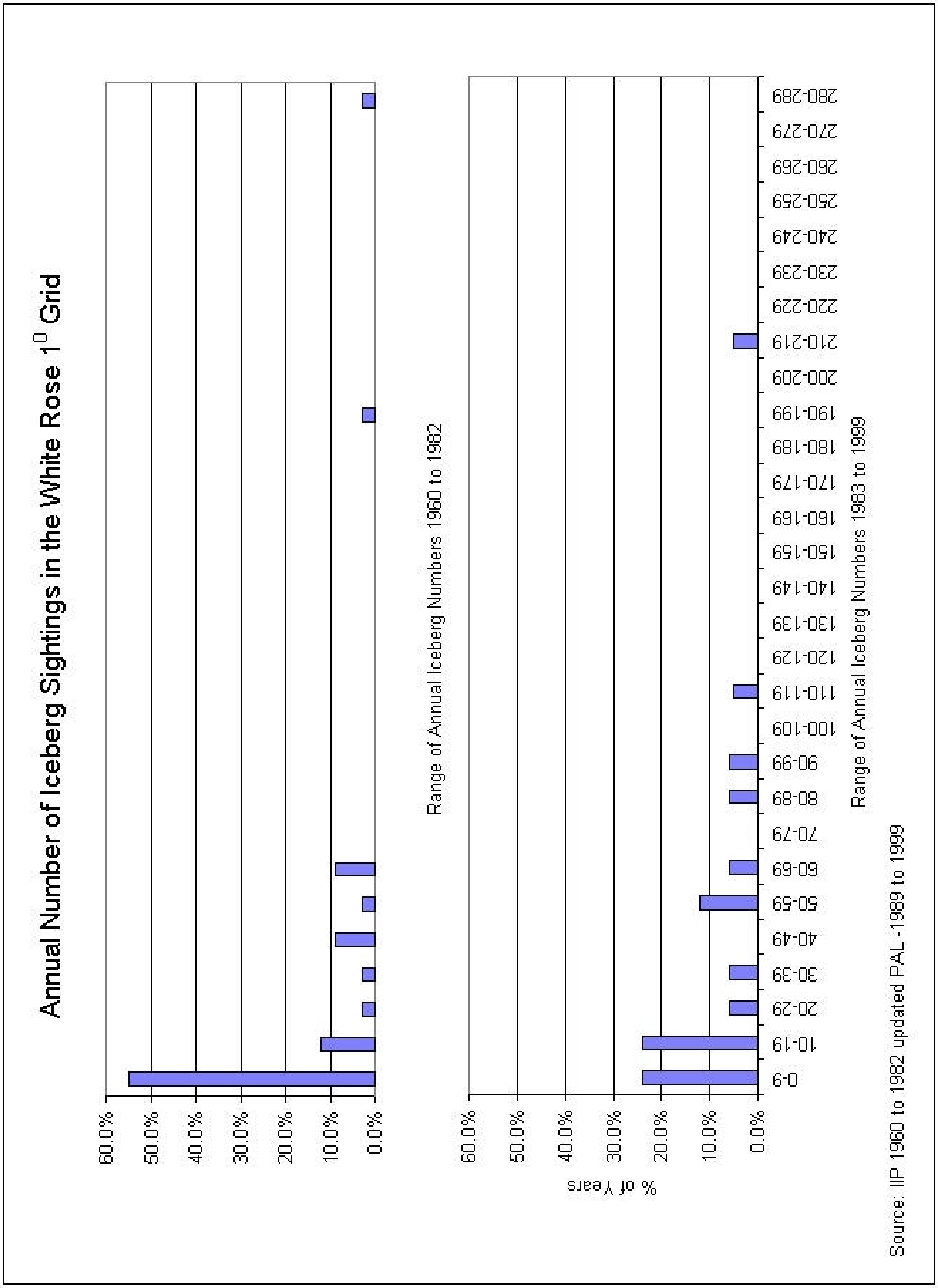
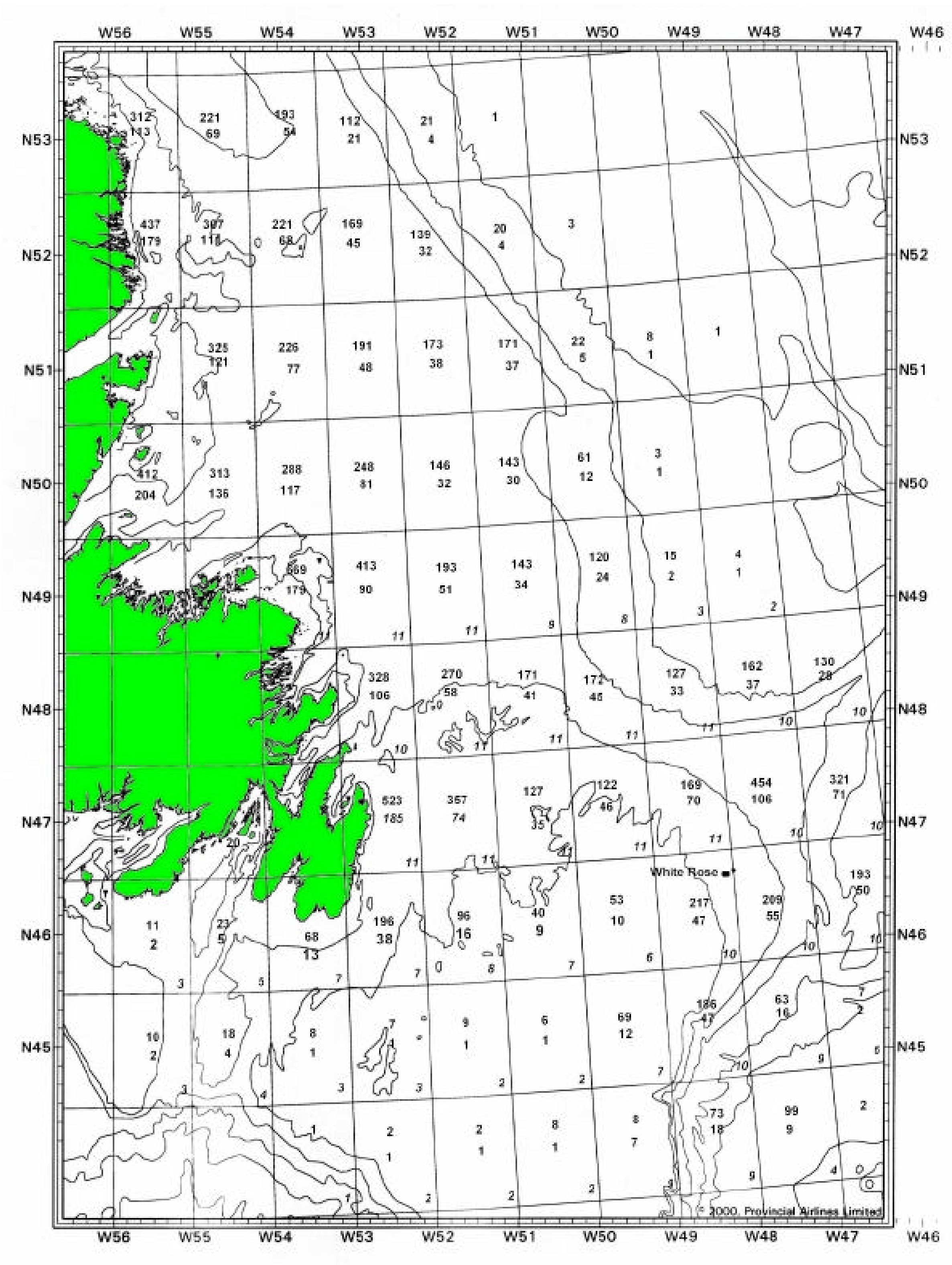


Figure 2.5–20 Maximum and Mean Annual Numbers of Icebergs Observed



Source: PAL Iceberg Sighting Database 1989 – 1999.

In general, these data show that icebergs are most frequent in the Avalon Channel adjacent to Newfoundland and over the northern and eastern slopes of the Grand Banks. These are regions where branches of the Labrador Current flow most strongly. The largest numbers of icebergs immediately adjacent to the White Rose grid tend to appear in the 1° grid immediately to the northeast. This area is traversed by the 200 m contour, which is associated with the approximate inshore edge of the outer branch of the Labrador Current.

2.5.3.3 Drift

Local winds and currents largely determine the movements of free-floating icebergs (that is, ungrounded icebergs in open water or in low concentrations of sea ice). When embedded in extensive fields of first-year or older sea ice, iceberg movements follow those of the adjacent ice, except when such ice is in an advanced state of decay. In the vicinity of White Rose, an area generally characterized by low-to-moderate concentrations of relatively thin sea ice, icebergs tend to move independently of the sea ice, reflecting the influence of deeper currents. Nevertheless, iceberg speeds and drift directions on the Grand Banks (Figure 2.5-21) as measured over one- to three-hour time intervals in the years 1983 to 1985 (Seaconsult 1988) are qualitatively similar to mean sea ice velocity fields (Figure 2.5-10). Approximately 65 percent of the measured speeds were less than 35 km/day and 47 percent were directed toward the southwest.

Equivalent plots of off-shelf drift data (Seaconsult 1988) show a greater prevalence of higher speeds and easterly through southerly drift. This indicates the dominance of the strong Labrador Current on the northern and eastern slopes of the Grand Banks.

2.5.3.4 Size Distributions

Icebergs are categorized by size, as defined in Table 2.5-2. These general size classifications have been in use for the past 30 years by all collectors of iceberg data (IIP, CIS and PAL). However, the accuracy of size distributions extracted from the various databases is questionable because most data are based on visual estimations and unspecified selection criteria.

Figure 2.5–21 Speed Exceedance and Velocity Direction Distributions

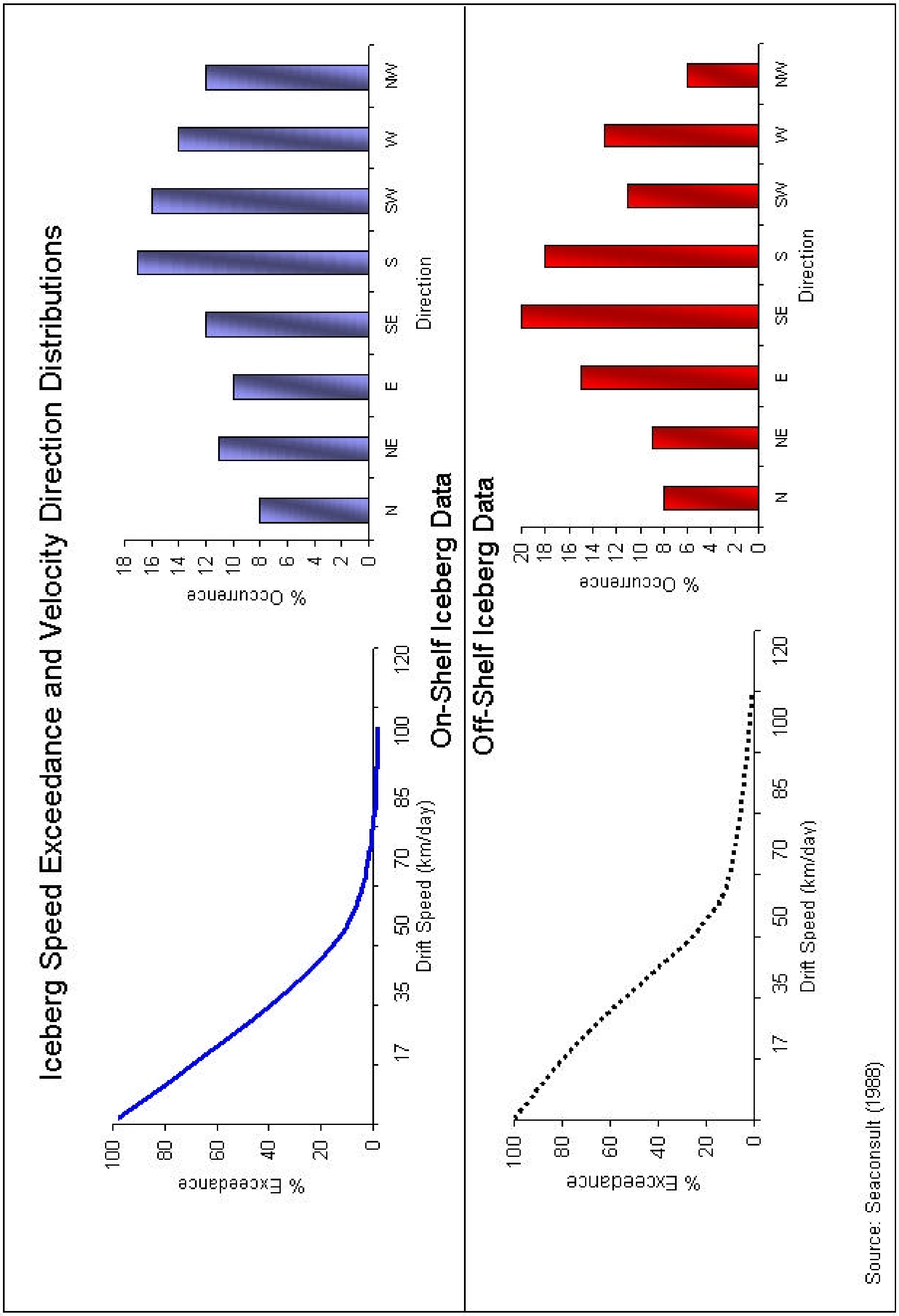


Table 2.5–2 Iceberg Size

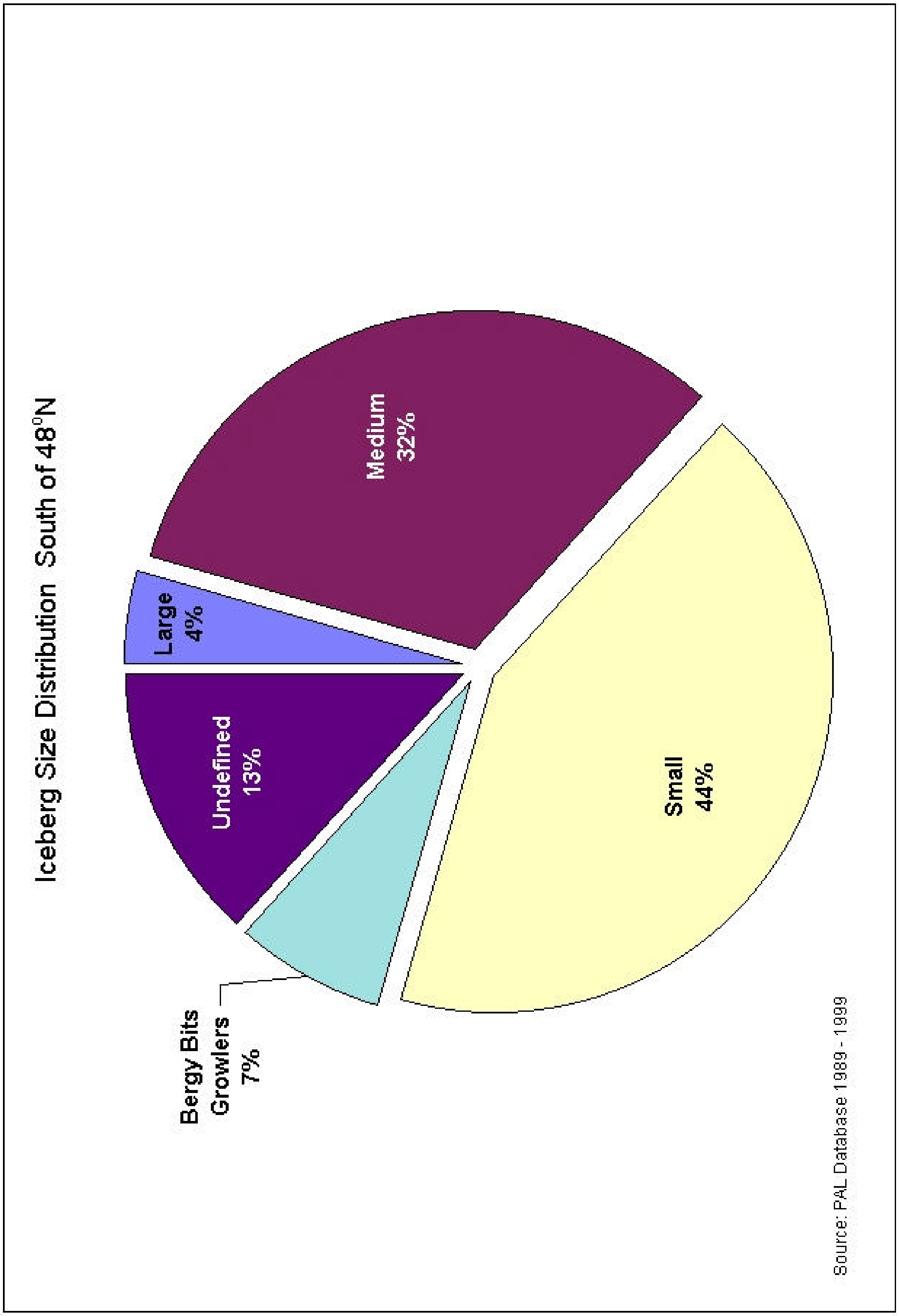
Category	Height (m)	Length (m)	Approx. Mass (T)
Very Large	> 75	> 200	> 10 Million
Large	45 – 75	120 - 200	2 - 10 Million
Medium	15 – 45	60 - 120	100,000 - < 2 Million
Small	5 – 15	15 - 60	100,000
Bergy Bit	1.0 – 5	5 - 15	10,000
Growler	< 1.0	< 5	1,000
Source: AES, MANICE April 1994.			

A recent PERD study, "A Compilation of Iceberg Shape and Geometry Data for the Grand Banks Region" (CANATEC 1999), lists dimensions for 872 icebergs measured on the Grand Banks and off Labrador, along with several interesting three-dimensional iceberg profiles. This database provides extensive measurement data (both above- and below-water) on icebergs. However, statistical plots of these data showed no significant differences compared to results obtained from earlier analysis (Seaconsult 1988) of industry data.

The PAL database of visually confirmed iceberg sightings and visually confirmed sightings extracted from IIP over the past 10 years have been analyzed to extract iceberg size distributions. Both data sets show that the majority (75 percent) of the icebergs south of 48°N fall within the small to medium categories (Figure 2.5-22). Using the same data and only considering iceberg size distribution at White Rose, this number rises to 99 percent. These results are comparable to those indicated in the PERD database.

Some size distribution data are available from various well history reports from the 1980s and early 1990s as a result of oil exploration activity on the Grand Banks and off Labrador. Through these reports, the dimensions and distribution of the larger icebergs have been reasonably well documented. However, these data sets contain only minimal data on bergy bits and growlers. As a result, it is not possible to ascertain reliable distribution data on these small ice masses.

Figure 2.5–22 Iceberg Size Distribution Based on 9,673 Sightings



Iceberg Length

The exceedance percentages for the waterline lengths of icebergs (Seaconsult 1988) are shown in Figure 2.5-23. This information is based on data gathered from surface vessel surveys in Newfoundland waters south of 49°N and east of 51°W. The on-shelf data corresponds to local water depths of less than 100 m while the off-shelf data corresponds to the local water depths at White Rose (greater than 100 m). The data show the effects of bathymetry on iceberg size distribution. These data show that the majority of icebergs within the White Rose area fall near the boundary between small- and medium-size, which relates well to the general size distribution (Figure 2.5-22) obtained from the aerial reconnaissance databases.

Also illustrated in Figure 2.5-23:

- negligible probability of icebergs longer than approximately 180 m in on-shelf areas;
- mean on-shelf iceberg lengths of approximately 70 m; and
- mean off-shelf iceberg lengths of approximately 80 m.

The 8 percent probability of on-shelf icebergs longer than 120 m is comparable to the 6 percent figure obtained from visual iceberg sightings, 1989 to 1995 (PAL 1995), for the White Rose 1° grid. There has been little systematic study of the spatial and temporal scales of variations in such distributions beyond basic distinctions between the on- and off-shelf regimes.

Iceberg Draft

The draft of icebergs in on-shelf and off-shelf areas as derived from side-scan sonar measurements on subsets of the icebergs represented in Figure 2.5-23 are shown in Figure 2.5-24 (Seaconsult 1988). In off-shelf areas, icebergs can have drafts larger than 150 m, while in on-shelf areas, iceberg drafts are in the 20 to 100 m range. Mean on-shelf and off-shelf draft are 60 m and 70 m, respectively.

The White Rose area is entirely in the “off-shelf” area as defined in the Seaconsult study. However, that area extended an indefinite distance to the east of their area of interest – the Hibernia-Terra Nova development areas. Consequently, those off-shelf iceberg drafts could include bergs that were not in the White Rose area either. As a result of this, the PERD database (Singh et al. 1999) was analyzed for icebergs within a 50-km radius of White Rose, a more representative area. One hundred and two iceberg measurement sets were extracted and the mean draft was found to be 42 m. Of these icebergs, just under 11 percent were classified as large and had a mean draft of 102 m. It is interesting to note that only three iceberg records showed a draft in excess of 120 m, the water depth of White Rose.

Figure 2.5–23 Exceedance of Waterline Lengths for On-Shelf and Off-Shelf Icebergs

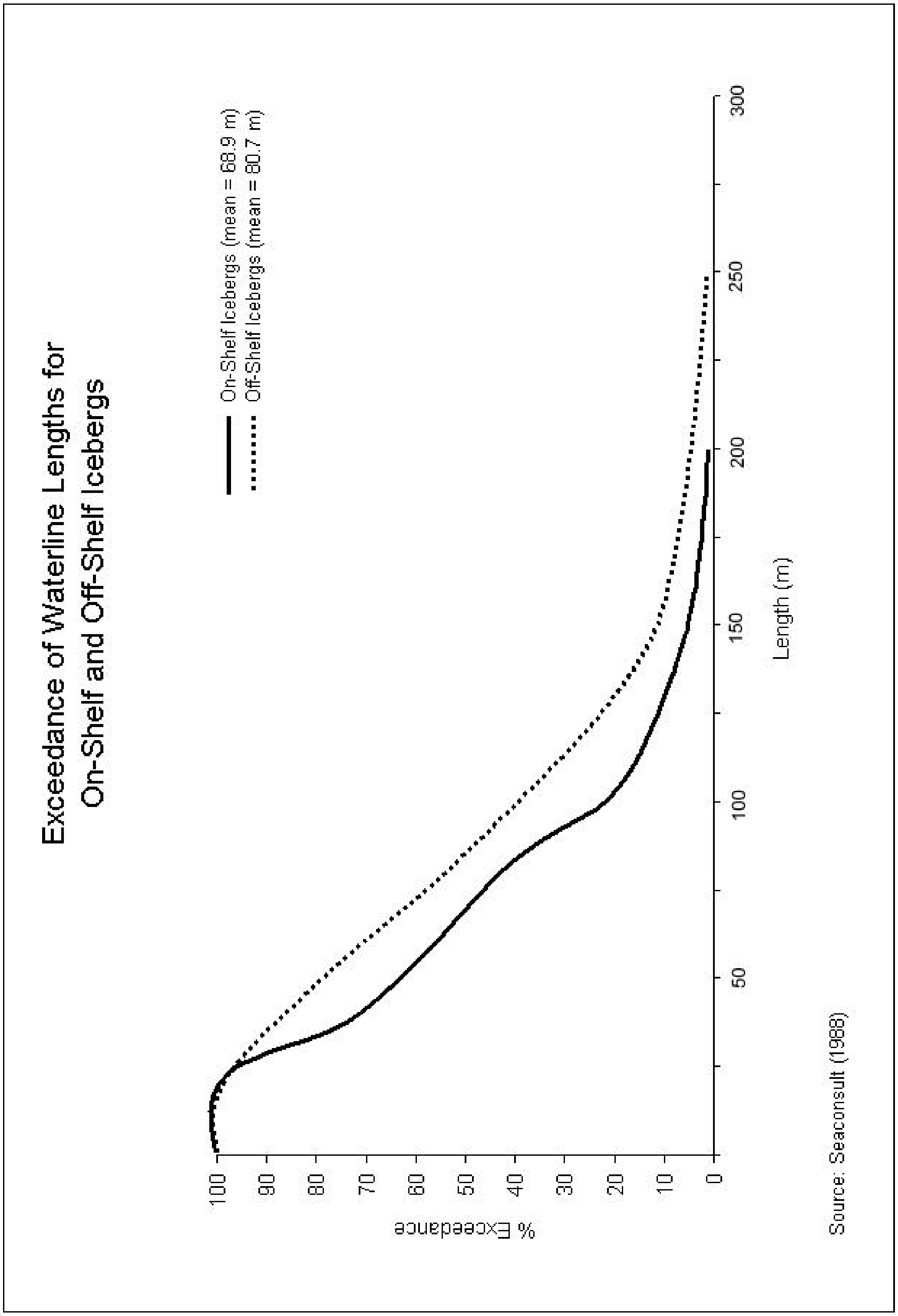
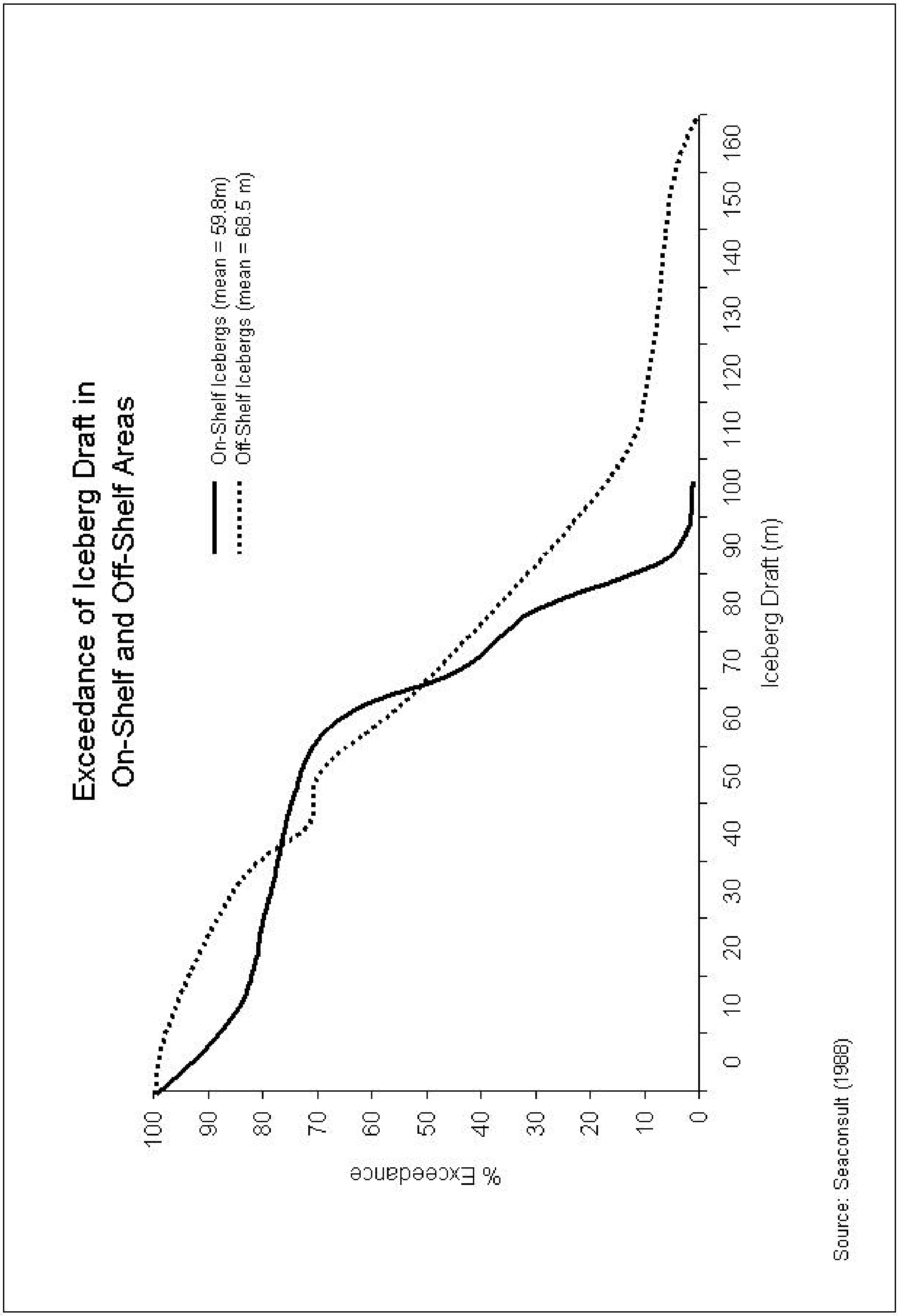


Figure 2.5–24 Exceedance of Iceberg Draft for On-shelf and Off-shelf Areas



It seems safe to conclude that while the White Rose location on the eastern edge of the Grand Banks is subject (regardless of the data sets used) to the slightly larger off-shelf icebergs, the 120 m water depth at White Rose would appear to offset any potential increase in ice/sea floor interaction.

Iceberg Height

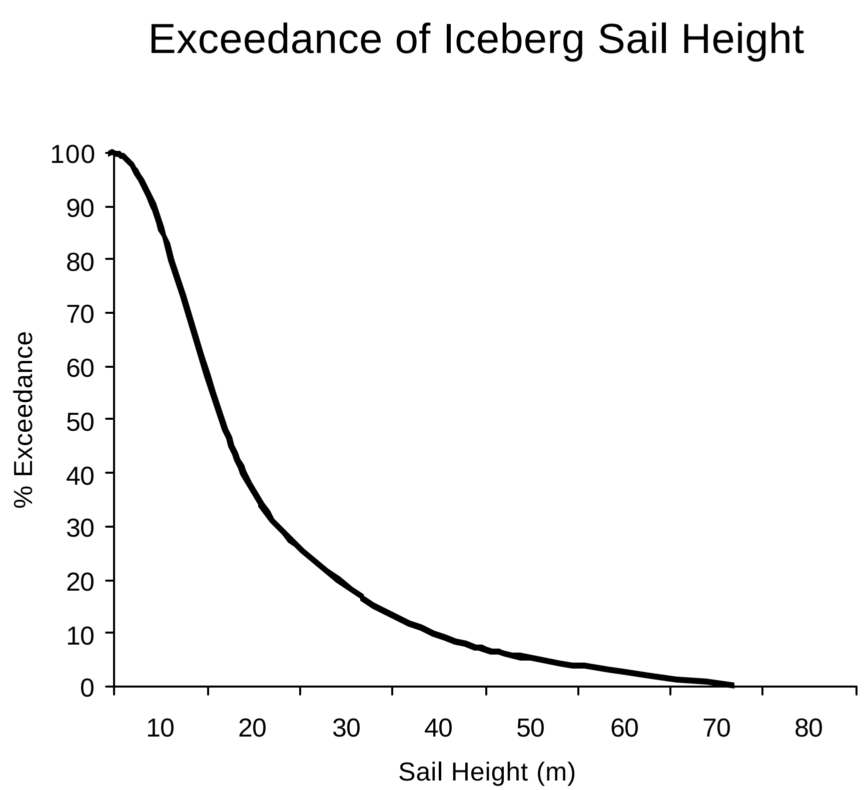
Data are available on above-water iceberg heights and on the overall masses of Grand Banks icebergs. Measurements of 113 icebergs on the northern Grand Banks (Ice Engineering 1981a; 1981b; 1982; 1983) (Figure 2.5-25) show median heights of approximately 20 m. Only 4 percent of the icebergs have heights in excess of 50 m, while 20 percent are at the other extreme of less than 10 m. More recently, the PERD database (Singh et al. 1999) gives 468 individual iceberg measurement sets. These data were compared to the results from the Ice Engineering data and show identical mean values based on 468 iceberg measurements.

A representative mass distribution derived for on-shelf regions from the data of Figure 2.5-23 is shown in Figure 2.5-26, using an empirically established connection between the mass in tonnes and 30 percent of the cube of the waterline length in metres (Crocker and English 1998). This approach to estimating the distribution of iceberg mass avoids the statistical problems posed by the small sample sizes used in most previous estimates.

A review of 224 icebergs measured near White Rose from the PERD database (Singh et al. 1999) shows similar results. For water depths greater than 100 m, the mean iceberg mass was 300,000 t, with nearly 10 percent in excess of one million t and 31 percent below 10,000 t.

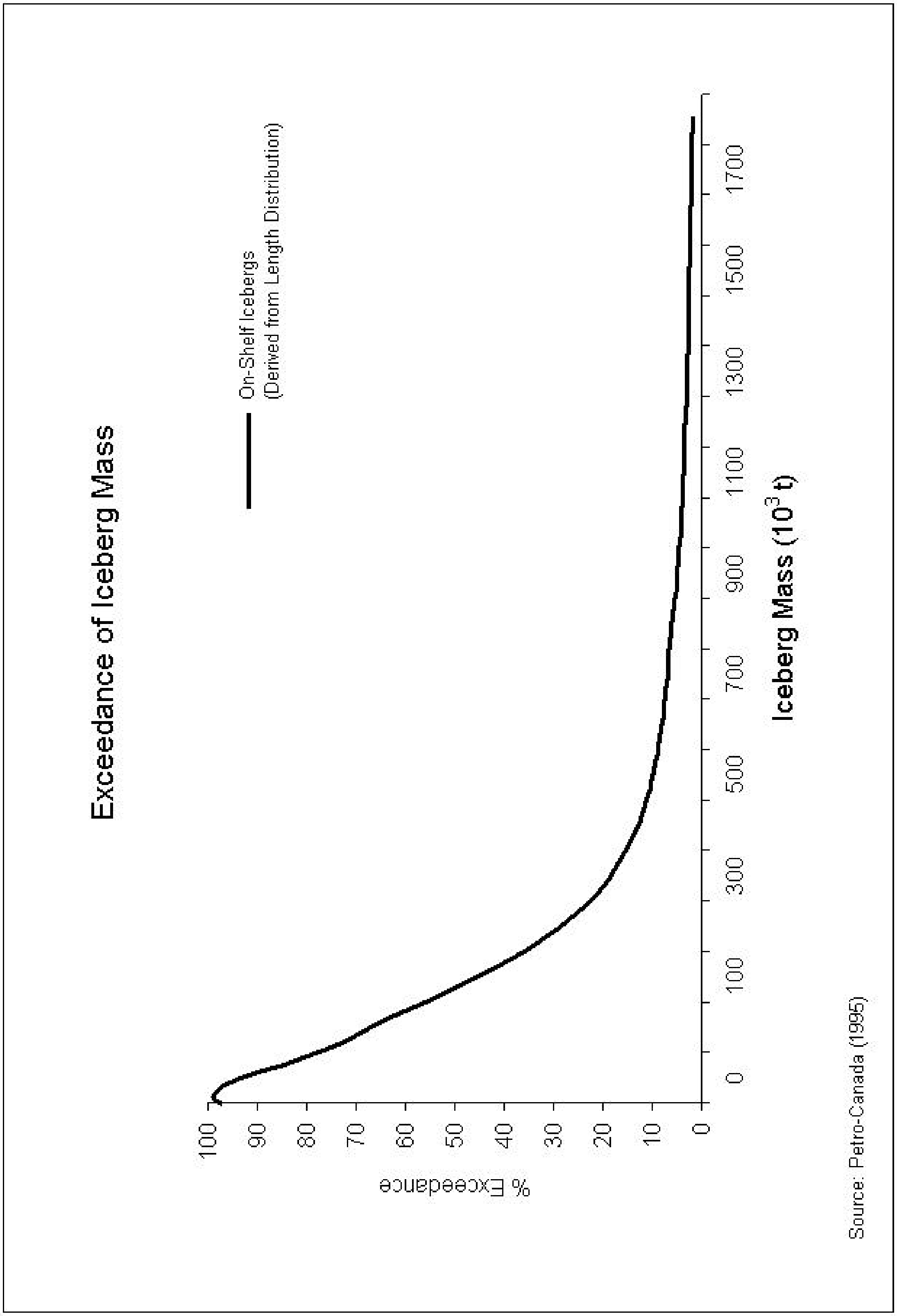
Only in recent years has substantial effort been given to systematic study of the bergy bits and growlers that comprise most of the smaller iceberg regime (lengths less than 20 m). Bergy bits and growlers also must be managed to ensure transport vessel and support vessel safety. Even though they are the smallest icebergs, they are still of substantial size, and they are more difficult to detect, particularly in high seas. Consequently, high operational priority has been given (Croasdale and Associates 1994) to the acquisition of detailed knowledge of these smaller members of the regional and local iceberg population. Measurements on several recently disintegrated icebergs (Crocker 1993) over a large, intensively surveyed area indicate that relative numbers of iceberg fragments are a function of length by a common negative exponential probability law (Marko 1996).

Figure 2.5–25 Exceedance of Iceberg Sail Height



Source: Ice Engineering (1981a,b, 1982, 1983)

Figure 2.5–26 Exceedance of Iceberg Mass



2.5.3.5 Deterioration

As discussed earlier, iceberg conditions at White Rose and on the Grand Banks are the result of accumulated deterioration in icebergs calved at least two years previously, primarily in West Greenland waters. Iceberg mass is lost all along individual drift trajectories, particularly where waves are strong and water temperatures are above freezing (Petro-Canada 1995). Natural deterioration of icebergs is accomplished in two ways:

- melting; and
- repeated calving into smaller fragments.

Of these two, the latter is the most effective because every fracture results in a greater surface area of ice exposed to melting. Calving usually occurs by the failure in overhanging ice ledges generated by the waterline erosion process. Other recent work (Marko 1996) suggests that ocean waves cause flexural failure as well. Repeated wave action on areas of naturally occurring structural defects causes the iceberg to fracture into two or more comparably sized fragments.

Loss of height through melt processes averages approximately 2 m/day on the Grand Banks and 4 m/day in the warmer waters south of the Banks. The IIP has studied iceberg melt rates over many years and has developed a melt rate table. It indicates the approximate number of days that various size categories of icebergs will take to melt at different water temperatures (Table 2.5-3).

Table 2.5–3 Iceberg Melt Rates

Water Temperature (°C)	Average number of days required to melt		
	Small Icebergs	Medium Icebergs	Large Icebergs
0	-	-	-
2	9	17	38
7	6	11	23
6	4	8	16
8	3	6	13
10	3	6	11
12	3	5	9
14	2	4	8
Source: AES, Ice Climatology 1984.			

2.5.3.6 Scour

Icebergs whose drafts exceed their water depths scrape along the sea floor, creating continuous or interrupted gouges and pits and may eventually become grounded in the seabed. These phenomena are known as 'iceberg scours'. While details of the scouring process are only partially known, it certainly depends on the following:

- sea bottom shape and composition;
- iceberg shape and stability; and
- strength of the current, wind and sea ice vector forces acting on the iceberg.

Evidence gathered off Labrador suggests that icebergs stabilized by adjacent dense sea ice generate long, continuous iceberg scours (Geonautics Ltd. 1989). Such icebergs, particularly in the thicker ice found north of the Grand Banks, have limited rotation about both vertical and horizontal axes, which are important determinants of scour characteristics (Woodworth-Lynas et al. 1985). These rotations, along with fracture and breakage of bottom-embedded keels, eventually produce icebergs with shallower draft configurations. In other circumstances free-floating icebergs may break in two or roll over, actually increasing their drafts and therefore increasing the chances of scouring the sea floor (Hodgson et al. 1988).

The dimensions and frequency of occurrence of iceberg scours have been studied to assess the likelihood of an iceberg affecting oil production facilities on or below the sea floor. Scour depths and probabilities have been assessed using a variety of techniques and various mixtures of data, including:

- sedimentation rates;
- iceberg numbers, drafts, velocities and densities; and
- age of existing scours.

Paulin (1992) reports that, for the northeastern area (which includes the White Rose development area) the maximum scour depth is 2.5 m and the maximum scour width is 124 m. This compares with a mean scour depth of 5 m, a mean pit depth of 10 m and a mean scour width of 100 m reported by Lewis et al. (1990). Basic scour data characteristics, as determined from side scan sonar surveys of the region from 46 to 47.5°N and 48.2 to 50°W are listed in Table 2.5-4. This area includes the White Rose development area. The observed scours began and ended in similar water depths and did not penetrate more than 1.5 m into the seafloor. These scour depths are well above any planned sub-sea installations proposed for the White Rose development.

Table 2.5–4 Descriptive Statistics for Iceberg Scour at White Rose

Coordinates for Northwest Corner 47.457°N 49.988°W			Coordinates for Southeast Corner 46.01°N 48.203°W	
Parameter	**Scour Length (m)**	**Scour Width (m)**	**Scour Depth (m)**	**Change in Water Depth (m)**
No. of records	62	53	53	-
Maximum	3,370	85	1.5	1.0
Minimum	60	7	0.0	0.0
Average	566.3	24.8	0.6	0.8
Std. Dev.	623.2	4.0	0.3	0.4
Note: These scour statistics are for water depths between 80 m and 100 m. Source: Petro-Canada 1995.				

The frequencies of scouring near White Rose relative to other Newfoundland offshore regions (in the form of contours of scouring density) are shown in Figure 2.5-27.

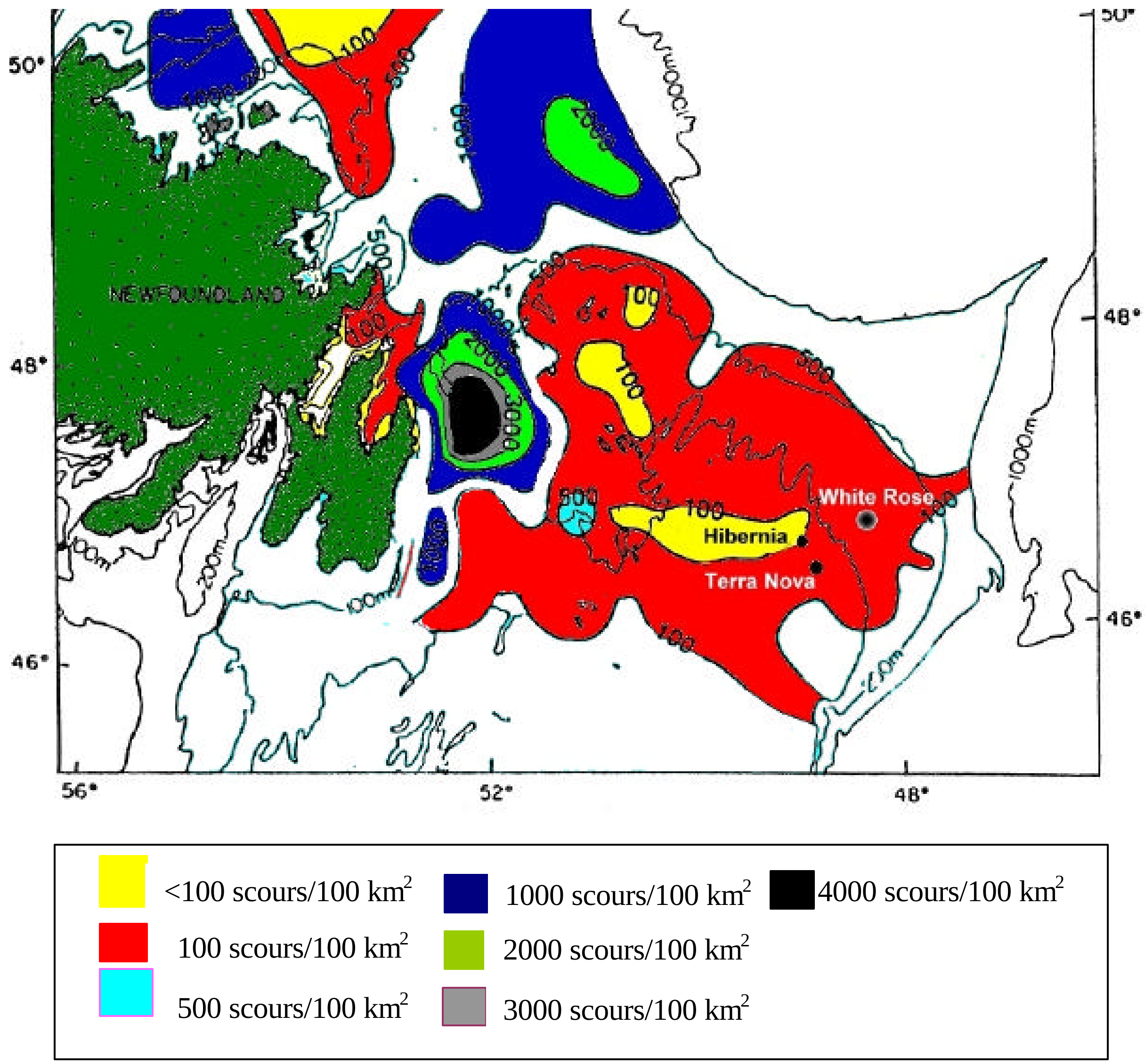
Highest scour densities tend to be concentrated, in spite of the deeper water, in the strong current regimes associated with the Avalon Channel, the outer slopes of the Grand Banks. Paulin (1992) also found that iceberg scour densities are low in water depths less than 100 m.

The more relevant studies on scour frequencies are summarized in Table 2.5-5, which illustrates the variability in calculated estimates of scour probability.

Table 2.5–5 Summary of Studies that Calculated Iceberg Scour Rates

Study	Assumptions Underlying Calculations	Scour Rate (scours per 100 km^2/yr)	Return Period (years)
Lewis et al. 1987	- Geological inference - Calculation of scour frequency from iceberg flux and draft estimation - Seabed mapping and remapping - Estimate of scour replenishment rates from estimates of sedimentary scour degradation	0.04 to 0.35	10 to 1
D'Apollonia and Lewis 1986	- Iceberg flux - Iceberg draft statistics	0.35	3
Gaskill et al. 1985	- Assumed sedimentation rates	0.0009	1100
Amos and Berrie 1985	- Scours as a function of megaripple migration	0.05 to 0.60	20 to 2
Banke 1989	- Analysis of iceberg drift tracks	0.020	50
Source: Banke 1989, plus supplemental.			

Figure 2.5–27 Density Contours of Areas of Observed Iceberg Scour



Iceberg scour probabilities generally do not take into account the possibility of active ice management (for example, towing (see following section for details)). Banke's (1989) study is the only one that analyzed actual iceberg grounding events during a historical time period when iceberg management was a viable option for control of icebergs. His low probability of scour rate may indicate the efficacy of a regime where active ice management is an option in controlling iceberg incursion into areas where undersea facilities are located.

In summary, while data in this area are inconclusive in estimating the probable number of iceberg scours expected over the life of the White Rose project, they do indicate that with active ice management, the total number of potential iceberg scours is very small. Any that did make contact with the sea floor would produce scours shallower than the depth of the proposed glory holes (11 m).

2.5.4 Current Ice Management Practices

This section provides an overview of ice management practices used by offshore projects to provide a safe environment and minimize operational disruptions caused by ice. Currently, ice management is comprised of:

- detection;
- monitoring and assessment; and
- physical management.

Ice management was first conducted by the offshore oil industry in the early 1970s (Bruneau and Dempster 1971) and continued to develop through the following three decades. Initially, ice management was a reactive process. However, as offshore oil operations expanded, ice management evolved into a proactive operation. Today, a coordinated approach is taken and decisions are made with respect to all operations being conducted on the Grand Banks. Physical management is conducted well upstream in an attempt to move any hazardous ice off the Grand Banks and out into the Flemish Pass, where faster moving currents will carry the ice safely past the operations areas.

2.5.4.1 Detection

Sea ice and iceberg detection (in various forms) has been conducted for most of the twentieth century. These early detection efforts were primarily conducted to provide warnings to mariners on where ice would likely be encountered and a typical vessel's response was to avoid these areas. Apart from fishing activity, which still allows a vessel to manoeuvre out of the way of threatening ice, offshore oil exploration is one of the few activities involving complex operations in ice-infested waters.

In the early days of exploration drilling off Canada's East Coast, dynamically positioned drill ships were used. As a result, most ice detection efforts were limited to detecting icebergs that drifted within radar range. With the increased use of moored semi-submersible drilling rigs in the early 1980s the need to detect and accurately locate ice at greater distances became critical.

Detecting small floating targets in open seas is a well-understood and documented process. Technological advances in the preceding two decades have improved ice detection capabilities to a point where both sea ice and icebergs can be detected and positioned over a large area with great accuracy.

Typically, oil exploration and production activities off Canada's East Coast use a combination of radar technologies and procedures to quantify and monitor ice distribution. Between government (both Canadian and U.S.) and private industry, there are over 5,000 h of airborne reconnaissance conducted annually over the Grand Banks and areas to the north. In addition to these radar-equipped aircraft, the areas off Canada's East Coast are swept daily by an assortment of satellite-based sensors and long-range, shore-based radars. Data from all these sources are integrated into a daily summary of ice distribution. The sequential ice distribution data are then used to monitor growth and movement. Using these procedures, operators are able to detect and monitor ice conditions 300 km or more upstream of the project, allowing for long-term resource and operational ice management planning.

If ice moves south of 48°N, dedicated radar-equipped ice reconnaissance aircraft are used to monitor the advancing ice. These reconnaissance aircraft are capable of extremely high probabilities of detection (POD) on even very small ice targets (Rudkin and Ripply 1988). In the unlikely event that any ice evades this detection network, most oil facilities are equipped with ice detection and monitoring radars that have been optimized for detection of small ice masses.

2.5.4.2 Monitoring and Assessment

Once detected, ice must be monitored to establish the speed and direction of its movement (drift) and, when enough information has been obtained, assess its potential threat to the project. Typically this is accomplished in stages. The initial detection is usually accompanied by a general classification of the type of ice or iceberg (Tables 2.5-1 and 2.5-2). As successive detections are made over an area, a general drift track is established. At this stage, the available data will allow only for general assumptions to be made. However, as discussed earlier, these initial data are used primarily for ice management resource planning. As ice closes in on the project area, more detailed information is required. The components of detailed ice assessment data are:

- physical dimensions of sea ice and/or icebergs;
- depth measurements of icebergs (draft); and
- accurate drift (direction and speed).

The standard methodology for obtaining physical dimensions comprises a mix of measurement, calculation and, in some cases, estimation, depending on the operational importance of the ice in question. Smaller icebergs and ice floes are usually estimated because their masses are well within the capabilities of ice management vessels. Larger icebergs, on the other hand, require more detail in regard to their overall mass and draft. Methods of measuring the above-water dimensions of icebergs were pioneered almost three decades ago and remain little changed today. These methods are described in the Grand Banks Operators' ice management plans and have been documented in many reports.

Once the above-water dimensions are known, calculations of overall mass can be made. These calculations are described in the Operators' ice management plans. However, it should be noted that due to the irregular shapes of icebergs, these mass calculations only represent an estimation of true mass. They can be in error by +/-20 percent (Comfort and Edwards 1987). Several studies were conducted during the 1980s in an attempt to establish a relationship between above-water size (height and water-line length) and iceberg draft. At best, these attempts provided only a first-order approximation. If the above-water-to-draft relationship shows the iceberg may be capable of running aground (scouring), then the operator must acquire more accurate data.

Obtaining accurate iceberg draft information is a long and sometimes complicated process, using underwater sonar deployed near the iceberg by an ice management vessel. This method has remained unchanged for nearly two decades. Although in the ensuing years the sonar units have improved in both accuracy and reliability, problems with deployment of the instrument and accurately manoeuvring the vessel near the iceberg remain.

Obtaining accurate drift information is a simple process of measuring distance over time. The widespread use of the Global Positioning Systems (GPS) now provides very accurate positions, permitting accurate tracks, even over short distances and time spans.

Once these baseline data have been collected, a reasonable assessment of the risk posed by the ice can be made. Typical risk assessment considers the following questions:

- Is the drift of the ice likely to pose a collision risk or disrupt operations?
- Is the draft of the iceberg sufficient to scour or strike sub-surface components of the project?
- Is the ice in excess of the design criteria of the facility?
- Is the ice/iceberg within manageable parameters?

If the answer to these simple questions is ‘no’, then the ice needs only be monitored for any drift changes. If, however, the answer is ‘yes’, then either a physical ice management procedure will have to be attempted or the facility will have to be secured and prepared for a possible move.

One of the key assessments is establishing collision risk. This is achieved by assessing a combination of:

- the ice;
- local winds;
- local currents; and
- forecasts and predictions of these components.

Several studies show that when reasonably accurate contemporary wind and current data are available, observed iceberg trajectories can readily be reproduced with simple physical-based models of iceberg drift. Results are relatively insensitive to model parameters such as air and water drag coefficients and, to some extent, iceberg dimensions and shape (Murphy and Anderson 1985; Smith 1993).

2.5.4.3 Physical Management

In general terms, most physical iceberg management consists of towing or deflecting the iceberg off its free drifting track. The first documented cases of iceberg towing were in 1971 (Bruneau et al. 1977). In simple terms, these first attempts consisted of deploying a long floating rope around the iceberg then applying force with a towboat in the direction they wished to move the berg. These procedures and the equipment used are described in detail in Total Eastcan’s iceberg towing manual (Eastcan Exploration 1973). In the ensuing 30 years, other methods have been used with varying degrees of success but this early method has remained the staple of iceberg management, having been used in nearly 500 documented iceberg tows.

The effectiveness of operational iceberg towing conducted during the 1980s has been studied (Bishop 1989). The conclusions were that, of 354 iceberg towing operations considered, 277 were successful with no difficulties, 74 were successful, but required several attempts, and 49 were unsuccessful. This translates into an effectiveness of 86 percent. Recently, much has been made of the criteria used in this study to define successful tows. However, since in most cases it is unknown what the free drifting track would have been if the iceberg were not towed, tow success can only be evaluated on one simple criterion: did the facility have to move? If not, the tow was successful.

Iceberg towing strategies employed in the exploration stages of White Rose consisted of attempting to deflect icebergs out over the edge of the Grand Banks, where the faster moving outer-branch of the Labrador Current would carry the icebergs south of the area. For the most part, this strategy worked well, as the tow distances involved are much shorter than those associated with other operations farther onto the Grand Banks.

Sea ice management procedures have been used much longer than iceberg management procedures and are well documented; breaking up sea ice to assist shipping is a commonplace occurrence in Canadian waters. Because of the loose nature of the pack in the area of the Grand Banks, sea ice management primarily consists of using support vessels to break up any large ice floes that meet or exceed the design limits of the facility.

Beginning in late 1988, all operators on the Grand Banks adopted a coordinated ice management approach. Under this system, the joint operators share ice information and ice management resources along with adopting a strategy and procedures for managing icebergs over the whole Jeanne d'Arc Basin area.

While the current ice management procedures are generally effective, allowing for safe and, for the most part, efficient operations, there are a few areas where improvements would be beneficial. Both the offshore operators and the authors of a recent PERD-sponsored report (C-CORE 1998) on ice management have identified problematic areas as:

- detection of small icebergs within pack ice;
- iceberg towing operations within pack ice;
- obtaining iceberg draft measurements reliably and efficiently;
- improved methods of attaching tow lines to icebergs; and
- cost effectiveness.

A joint industry, academic and private enterprise initiative has been started to address these and other issues related to ice management. In addition, several studies and reports, primarily under the auspices of PERD are being conducted with a view to addressing some of these issues and providing, among other things, cross-indexed databases of existing ice and iceberg data.

2.6 GEOLOGY

2.6.1 Geological Overview

Seabed physiography is defined by sedimentological processes related to ocean waves and currents, sea ice movement, global sea level changes, sediment slides and slumping, and glaciation during the Tertiary and Quaternary periods. The accepted view of recent sedimentation is that the top of Grand Bank was exposed during the late-Wisconsin. Sea level subsequently rose, surficial sediments were reworked, leaving a relatively thin veneer of sand and gravel overlying an angular unconformity that truncates the sediments of the Banquereau Formation (Fader and King 1981; Stoffyn-Egli et al. 1992). Recent processes including iceberg scouring, sediment slumping and the actions of waves and currents have been observed. Thick sedimentary sequences were deposited along the western margin of the Atlantic, in several sedimentary basins (Figure 2.6-1).

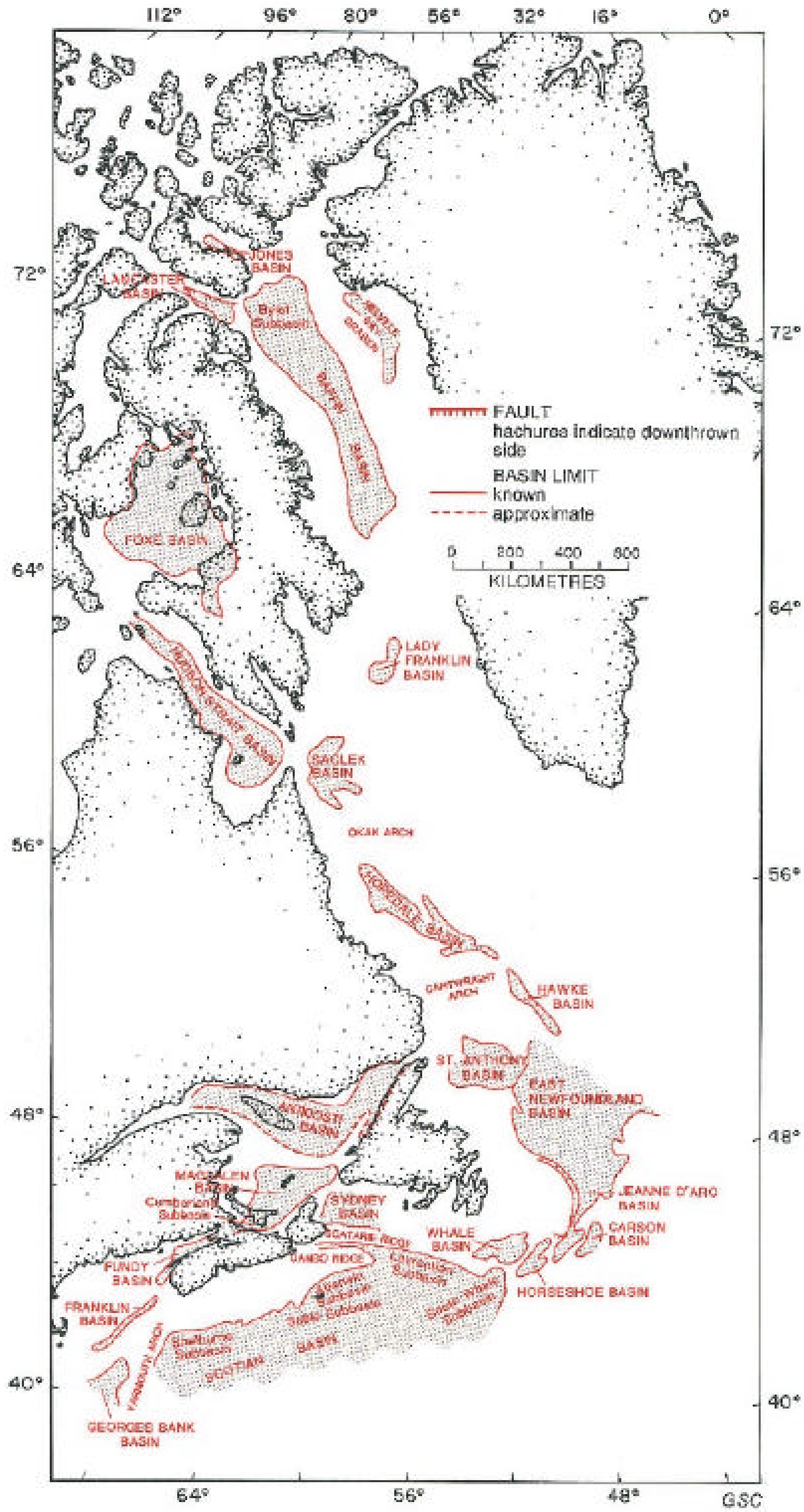
2.6.2 Physiography and Surficial Sediments

The Grand Banks form a series of shallow outer banks separated from the coast by irregular inner shelf basins, including the Avalon Channel and the St. Pierre Channel. This dynamic shelf is vulnerable to wave and current action, and iceberg scouring.

The surficial geology and shallow (#1000 m) sub-seabed stratigraphy of northeastern Grand Bank, off eastern Newfoundland, have been the focus of numerous investigations over the past three decades. Site-specific studies have been conducted for oil companies by private geophysical contractors, while large scale regional surveys have been conducted by staff of the Geological Survey of Canada (GSC) (Atlantic) in Dartmouth, Nova Scotia.

The regional stratigraphy is defined by gently dipping Tertiary sediments of the Banquereau Formation (Fader and King 1981). These rocks are typically interpreted to consist of marine clastic sediments, deposited within a shelf environment. For the most part, observed reflections are parallel and continuous, and dip to the (east) northeast at less than a 1° angle (Sonnichsen et al. 1994). Within the White Rose area, well site surveys have concurred with this overview (McElhanney 1981; 1982).

Figure 2.6–1 Sedimentary Basins of Offshore Eastern Canada



1401-13.cdr 23JUN00 Figure 2.6-1

Source: Bell and Campbell 1990

At present, the accepted view is that the top of Grand Bank (everything above the present 110 m bathymetric contour) was exposed during the late-Wisconsin (approximately 15,000 years ago). Sea level subsequently rose, surficial sediments were reworked, and the result was a relatively thin (average 1 to 3 m) veneer of sand and gravel overlying an angular unconformity that truncates the sediments of the Banquereau Formation (Fader and King 1981; Stoffyn-Egli et al. 1992). The seabed within the White Rose area, at a depth of 120 to 130 m, is typified by fine to medium grained "Adolphus Sand". These sediments were likely deposited within the shallow region along the margin of the exposed bank top, during and after the last sea level lowstand (Fader and Miller 1986).

The distribution of surficial sediments on the Grand Banks has been mapped and classified over large areas, on the basis of existing data and extrapolation, using water depth and geographic distribution. At the same time, a regional shallow (< 100 m) seismostratigraphy has been developed based upon the presence of an extensive progradational sequence in the shallow subsurface (the "Hibernia Delta"), and its relationship with gently dipping shelf sediments of the Banquereau Formation above and below. Recent studies (for example, Terraquest Associates 1993; 1994) have extended this stratigraphy from the Hibernia region, where it has been studied in detail, to regions north and south, and to the Terra Nova discovery site. This correlation has been based upon high resolution seismic profiles, with some correlations made with geotechnical boreholes. Distal equivalents of these progradational sediments are likely present within the sub-surface at White Rose, but are probably to be marginally sandier, on average, than the shelf sediments above and below.

2.6.2.1 White Rose Site

The White Rose site is situated on the northeast margin of the Grand Bank. Water depths gradually increase to the east-northeast, in keeping with regional trends. Slopes appear to be fairly consistent.

Side scan sonar images of the White Rose area (Fugro Jacques GeoSurveys 1999a; 1999b; Nortec Jacques GeoSurveys 1998) indicate that the surficial geology is a thin veneer of fine to medium grained sand over a coarser substrate, consisting of gravel and gravelly sand (Table 2.6-1). Variable concentrations of benthic organisms (such as, starfish, brittle stars, bivalves, etc.), as well as cobbles, are present. The generally "mottled" appearance of the seabed is interpreted to originate from the underlying and occasionally exposed gravel "lag" surface, formed when glaciogenic sediment was reworked during the last sea-level lowstand. This underlying surface displayed evidence of moderate (relict) scouring on side scan sonar mosaics, consistent with observations from other side scan surveys in the region (GSC Atlantic survey programs) and indications from high resolution seismic data. As such, some of the gravel occurrences in the area may correspond with old scour berms, and may have positive relief (that is, form gentle mounds). The site survey results are supported by sediment samples and observations made during the 2000 Baseline Monitoring program recently conducted.

Table 2.6–1 Stratigraphy of Substrate in White Rose Area

Formation	Lithology	Thickness (m)	Remarks
Adolphus Sand	Sand (fine to medium sand, relatively hard packed)	0 to 3	Sub-littoral deposits formed seaward of the late Wisconsinan shoreline. Occurs in water depths greater than 100 m.
Grand Banks Drift	Sand and gravel (and cobbles)	2 to 10	This unit is composed of two facies: a normally consolidated facies deposited in basinal areas and over much of the Grand Banks, it is often interbedded or underlying the Downing Silt, and an overconsolidated facies that occurs over large areas of the Grand Banks, often underlying the normal consolidated facies. It is in unconformable contact with the underlying Banquereau Formation.
Banquereau Formation (Tertiary)	Clay with cobbles (claystone)	10 to 700	The unconformity is related to subaerial and glacial erosion. Seaward dipping beds are dominantly shales and mudstones.

The only seabed features are related to seabed disruption by iceberg scouring, or by the dragging of otter trawl "doors" during fishing activities. Otterboard trawl marks were well defined during the 1981/82 surveys (McElhanney 1981; 1982). Past interpretations of biota present in seabed photographs have suggested that the seabed is relatively stable, with relatively little sedimentary transport within the region (such as, McElhanney 1982). This is supported by recent (Fugro Jacques GeoSurveys 1999a; 1999b; Nortec Jacques GeoSurveys 1998.) mapping exercises from the region, which clearly display anchor marks from old drilling programs, preserved in sand after 15 to 20 years. As would be expected, preservation levels are highly dependant on water depth.

2.6.3 Iceberg Scours

Iceberg scours and pits, resulting from the grounding of icebergs, are common features on the margins and regions of Grand Bank. Scours may be curved or linear furrows with berms at the sides, or elliptical or circular pits. Scours observed in water depths of < 110 m are considered to have formed since the exposure and transgression of the bank top. An older population of seemingly relict scours is present in deeper water, occasionally overprinted by more recent occurrences. Such features are evident within side scan sonar and swath bathymetry images in the White Rose area, as well as on sub-bottom profiler records. Significant efforts have been made to date to quantify the rate of present-day scouring, although with limited success. Some of this work has been conducted within the White Rose region, using observed scouring events by grounded icebergs (such as, Banke 1988; Woodworth-Lynas 1989).

Recent mapping of the White Rose area has defined possible "new" scours (Terraquest Associates 1997). In 1988, a grounding was observed and documented. Between April 2 and 13, 1988, Berg #100 was observed in the region of White Rose. On April 12, 1988, it grounded in 123 m of water. The estimated mass of the berg was 1,900,000 tonnes (Banke 1988; Woodworth-Lynas 1989).

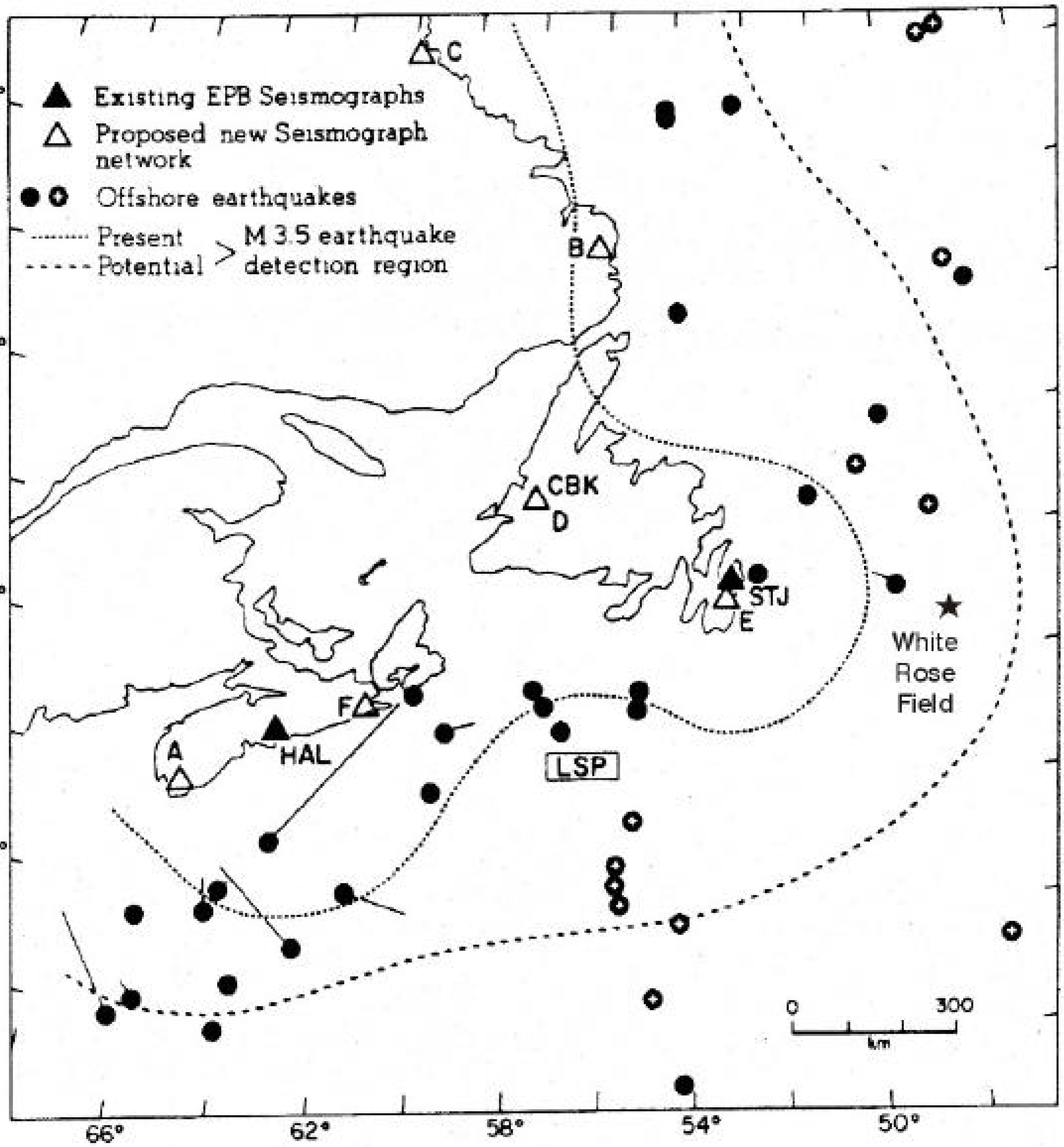
A subsequent study revealed the presence of a scour sequence: a touch-down scour, the scour/grounding event and the lift-off from the grounded position (Woodworth-Lynas 1989). Scour depth ranges from 0.5 to 1.1 m, with a width of 20 to 35 m. In a follow up to this, Terraquest Associates (1997) showed that the total length along the scour was 1,430 m. In the White Rose area, scours generally trend from the northeast into the shallower water in the southwest.

Sonnichsen (1998) examined an area with a high population of scours to the north of White Rose. He observed both pits and furrows. Older scours were documented, and depth, length and width were found to be varied. Pits ranged from 1 m deep and 50 m across to up to a maximum depth of 8 m and 80 m across, and often occurred in close association with one or more pits, suggesting repeated impact or grounding by an iceberg. Sonnichsen (1998) observed furrows, some in excess of 7 km with most excavating greater than 1 m below the seabed.

2.6.4 Seismicity

The White Rose area located on the northeastern edge of the Grand Banks is observed to be an area of relatively low seismic activity. The Charlie-Gibbs Fracture Zone-Dover Fault, the Newfoundland Transform Fault and the eastern edge of the continental shelf, bound the area. Past seismic events are not well documented for the offshore, particularly for earthquakes with magnitudes less than 5 (Seaconsult 1988; Adams 1986) (Figure 2.6-2).

Figure 2.6–2 Map of Earthquakes Off Canada's Southeastern Margin



Note:
LSP is the Laurentian Slope Seismic Zone. Dots indicate corrected position of offshore earthquakes. Open dots are earthquakes found from a re-examination of the seismograms. Fine line shows the offshore limit of complete detection of earthquakes of magnitude 3.5 and larger since 1983.

1401-17.cdr 23JUN00 Figure 2.6-3

Source: Adams 1986

The Laurentian Channel located along the Newfoundland Fracture Zone is the most seismically active portion of the Newfoundland Continental Shelf. Most of the earthquakes occur in the Laurentian Slope Seismic Zone (LSP) and are thought to be associated with the Glooscap Fault part of the Newfoundland Fracture Zone (Seaconsult 1988). In 1929, a magnitude 7.2 earthquake occurred with aftershocks as high as magnitude 6. Hasegawa's (1991) re-examination of the data was unable to determine if the slump that generated the 1929 tsunami was the result of an earthquake of approximately magnitude 6 or the result of a mini-slump that coalesced into a major slump. In 1951, 1954 and 1987, earthquakes with magnitudes ranging around 6 occurred in the same area (Seaconsult 1988).

The White Rose field is located over 650 km northeast of the Grand Banks 1929 earthquake epicentre. The dots in Figure 2.6-2 represent the location of offshore earthquakes. The open circles are the locations of earthquakes determined by re-examination of the Corner Brook seismograms. Prior to 1956, the records of magnitude 5 events is probably not complete, and the record of magnitude 4 earthquakes in the area is not complete prior to 1965 (Seaconsult 1988).

The earthquake study area is located on a stable cratonic block and all identified oilfield sites are within the seismicity Zone 1. This is based on a scale of 0 to 5. Zone 0 is represented by the Aseismic Gulf of Mexico, while areas of severe seismic activity such as the Gulf of Alaska, are Zone 5.

2.7 SHORELINE ENVIRONMENT

The shoreline environment is discussed in detail in the Terra Nova Development Plan Application Environmental Impact Statement (Petro-Canada 1995). The following sections are derived from that document and provide a general overview of the shoreline environment.

2.7.1 Coastal Geomorphology

Shoreline sensitivity data have been collected by aerial video surveys in the early 1980s for southeastern Newfoundland by Mobil Oil. Northeastern Newfoundland shorelines from St. Anthony to Trinity Bay were surveyed by Petro-Canada.

The portion of the Newfoundland coastline described in this section extends from Cape St. Francis on the northeast tip of the Avalon Peninsula to Point Crewe at the tip of the Burin Peninsula. Based on the predicted movement of oil in the water, this is the shoreline area that could be impacted by a spill should one occur in the offshore development area (Mobil 1985).

Newfoundland's eastern coastline is generally characterized by rocky headlands and steep cliffs with few, discontinuous pocket beaches and baymouth bars, or barachoix. The shoreline varies from being deeply indented (the result of preferential erosion along unresistant faults, folds and erosive bedrock) to straight with few embayments (as along the Cape Shore of Placentia Bay where bedrock structure parallels the coast) (Catto 1994).

To a large extent, the development of this coastline has been strongly influenced by the effects of the last glaciation. This influence is reflected by the predominantly pebble-gravel beaches that occupy 53 percent of the coastal backshore areas, and the rarity of sand-dominated beaches that occupy less than 1 percent of the shoreline (Forbes 1984; Shaw and Forbes 1987; Catto 1994; Liverman et al. 1994; Mobil 1985; Newfoundland Geological Survey Branch unpublished data).

In an effort to characterize the beaches of Newfoundland's eastern shoreline, Catto (1994) has grouped these areas into three categories:

1. exposed systems;
2. low- to moderate-energy coves; and
3. high-energy coves.

Exposed systems are those beaches that have developed along open coastlines where both shore-normal and shore-parallel (or longshore) currents govern sediment deposition and erosion. These beaches, typically found in Placentia Bay, derive their sediment from glacial till deposits located upcurrent.

Low-to-moderate and high-energy cove systems are well represented along the eastern coast of the Avalon Peninsula (that is, the "Southern Shore"). These beaches are typically characterized by dominantly shore-normal sediment transport and derive their sediment from nearby cliffs of bedrock or glacial till. This pattern of sediment transport implies that sediment and contaminants, once introduced into a beach system, will remain within the cove for a considerable period and will be less likely to migrate laterally along the shoreline (Catto 1994).

A number of studies have shown that sea level is progressively rising around the Avalon Peninsula at rates of up to 7 mm/yr. This is manifested by coastal erosion rates approaching 1 m/yr at some beaches. To some degree, this erosion is the result of historic anthropogenic influences such as aggregate quarrying and construction near the shoreline. However, coastal areas relatively untouched by humans have also shown this pattern (Taylor et al. 1990; Catto 1994; Liverman et al. 1994). A joint coastal monitoring program has recently been initiated by the Newfoundland Geological Survey Branch and the Geological Survey of Canada to measure the changing nature of this shoreline.

2.7.2 Hydrology, Oceanography and Ice

Rivers in the northern Avalon Peninsula are typically small in total volume discharge, with a strong seasonal variation resulting from the annual cycle in precipitation. Overall, the amount of freshwater input into shoreline waters is modest, given the comparatively low area of land drainage relative to the large lengths of shoreline around the Avalon and Burin peninsulas. Generally, local freshwater runoff is small in comparison to that arising from the melting of sea ice in spring in coastal areas, and on the northeast Newfoundland Shelf.

The tides experienced along the coastlines are moderate in size, with normal tidal heights of approximately 1 m (Section 2.4). Along the south coast, including Placentia Bay, the tide is predominantly semidiurnal (two highs and two lows each day). Off the east coast of Newfoundland, the tide can be characterized as mixed, mainly semidiurnal (Godin 1980).

Ocean currents in the exposed outer coastal areas are dominated by the southward flowing inner branch of the Labrador Current (Petrie and Anderson 1983; Petrie 1991; Narayanan et al. 1995). The inner branch of the Labrador Current has typical speeds of 0.72 km/h (20 cm/s) (approximately 0.5 mph), and is centred over the Avalon Channel, an underwater trough separating the coastline from the western side of the Grand Banks (see Section 2.4). Southward flows along the exposed portions of the shoreline, such as headlands, can be expected to be considerably larger than the mean flows at times. This results from the combination of the longshore drift, tidal currents and undertows induced by waves breaking along the coast. The Labrador Current turns westward after rounding Cape Race, and a branch of this current exhibits a cyclonic, re-entrant pattern in the mouth of Placentia Bay.

Within the major bays along the coastline, the local circulation can be markedly different than that on the outer coast. The circulation within Trinity Bay (Yao et al. 1988) and Conception Bay (deYoung et al. 1993; deYoung and Sanderson 1995) has recently been studied. Generally, the mean current speeds are lower (2 cm/s) in these two large bays than those along the outer coastlines. In most of the area, the flow speeds are controlled by the local underwater topography, with the basin shape playing an important role in defining the characteristics of the flow field. Tidal flows in the bays are also weak, with typical speeds of a few centimetres per second or less for the dominant semidiurnal tidal constituent. Given the generally weak and variable circulation, the residence time for water and any drifting matter, including pollutants, is much longer than for the offshore regions, deYoung and Sanderson (1995) estimate residence times in Conception Bay as approximately 40 days.

Exposure to ocean waves is a major determinant of shoreline characteristics, as discussed above. The large ocean waves that occur in the offshore area (Section 2.2) have very high energy levels as they impinge on and break along the exposed outer shoreline. Again, within the larger embayments, and in areas sheltered by offshore islands, the exposure to ocean waves is much reduced, resulting in much different beach types in these areas.

Sea ice is also a seasonal factor in the shoreline environment. It can disturb the shoreline during break-up (through bottom scouring), or in more sheltered locations where it can be a landfast ice cover, it can protect the shoreline from waves and strong currents. Pack ice often covers the shoreline from mid-March to late April. In the major bays, the pack ice tends to remain in place for extended periods, while along the exposed offshore shorelines it is moved quickly through the area by local winds and currents.

2.8 CHEMICAL ENVIRONMENT

2.8.1 Water Chemistry

2.8.1.1 Dissolved Oxygen

The concentration of dissolved oxygen (DO) in seawater strongly influences the distribution of marine life. Oxygen in the form of O_2 is necessary for the survival of most organisms. DO is used by organisms in two main pathways, namely chemically (chemical oxidation of organic matter) and biologically (plant, animal and microbial respiration).

There are two methods available to introduce oxygen into seawater, both of which are limited to the near-surface region of the ocean. The two sources of DO are:

- production of oxygen by photosynthetic marine organisms; and
- transfer of oxygen from the atmosphere to seawater.

Numerous physical, chemical and biological factors determine the horizontal and vertical distribution of dissolved oxygen in the water column (Sable 1991). DO concentrations vary seasonally as a result of changes in water temperature and salinity, and vary continually through the physical process of mixing. The DO concentration in the Grand Banks water column has been reported to be fairly uniform during the spring, with a mean surface value of approximately 8 mg/L, decreasing to approximately 7 mg/L near the bottom (Levy 1983). Similar results were reported by a mid-spring 1993 survey of the Grand Banks, which recorded DO concentrations of 9.5 mg/L at the surface and 7.5 mg/L near the bottom (Colbourne 1993). The increased DO values from March to May were explained by the timing of the survey during the annual plankton bloom, which generally occurs from late March to early April on the Grand Banks (Colbourne 1993).

2.8.1.2 Suspended Particulate Matter

Suspended particulate matter (SPM) may be composed of microscopic biota, clay, silt and attached nutrients (organic and inorganic) that are held in suspension in the water column by currents. The concentration of SPM affects water clarity, which partly determines the penetration of light into the water column and, by extension, influences primary production. SPM occurs naturally and concentrations vary seasonally through changes in mixing and primary production. There are also human-induced sources of SPM such as sewage and industrial effluent, dumped dredge materials, or drill mud effluent.

The reported range for SPM in the Grand Banks water column is 0.01 to 2.77 mg/L and is within ranges reported for other ocean environments (MacKnight et al. 1981 in Mobil 1985). Water samples collected at the Terra Nova oilfield site (Table 2.8-1) indicate that total suspended solids (TSS) is homogeneous throughout the water column, with a mean value of 2.26 ± 2.27 mg/L at the surface, and 2.17 ± 1.93 mg/L near the bottom (Petro-Canada 1998).

2.8.1.3 Inorganic Nutrients

Inorganic nutrients such as silicates, nitrates and phosphates occur naturally in aquatic systems and provide essential nutrients for phytoplankton. The concentrations of these nutrients also vary seasonally and are affected by currents, water column stability and phytoplankton abundance. In general, nutrient concentrations are low in surface waters during the summer months following the spring phytoplankton blooms. Concentrations generally increase in the fall due to water column mixing (Petro-Canada 1995).

2.8.1.4 Trace Metals

Large concentrations of essential metals (for example, copper, zinc, iron, vanadium, chromium) and low concentrations of other non-essential metals (for example, mercury, cadmium, lead) may be toxic to living organisms. The results of two studies that measured the levels of trace metals in seawater from the Grand Banks and specifically from the Terra Nova Oilfield site are provided in Table 2.8-2. Water chemistry has not been conducted at the Hibernia site (HMDC 1995) or at the White Rose site. Data from the Grand Banks study (MacKnight et al. 1981) indicate the area is typical of open water concentrations of trace metals and variability was attributed to natural spatial and temporal variability or analytical techniques. Therefore, trace metal concentrations are reasonably expected to not differ significantly in the relatively small area of the Grand Banks.

Table 2.8–1 Summary Statistics for Water Chemistry Data (Inorganic Variables) from the Terra Nova Oilfield Site

Inorganic Analytes	LOQ*	Units	Number of Samples	Number of Samples > LOQ	Mean ± Standard Deviation	Median	Min	Max
			Surface					
TSS	< 0.5	mg/L	10	5	2.26 ± 2.27	1.05	< 1	6.3
Arsenic	< 0.1	µg/L	10	10	1.09 ± 0.33	1.05	0.7	1.7
Cadmium	< 0.1	µg/L	10	0				< 0.1
Chromium	< 0.5	µg/L	10	0				< 0.5
Cobalt	< 0.1	µg/L	10	0				< 0.1
Copper	< 0.1	µg/L	10	10	0.60 ± 0.12	0.3	0.2	0.6
Iron	< 1	µg/L	10	0				< 1
Lead	< 0.1	µg/L	10	0				< 0.1
Manganese	< 1	µg/L	10	0				< 1
Nickel	< 0.5	µg/L	10	0				< 0.5
Zinc	< 1	µg/L	10	0				< 1
Mercury	< 0.05	µg/L	10	0				< 0.05
			Middle					
TSS	< 0.5	mg/L	10	3			1.8	3.6
Arsenic	< 0.1	µg/L	10	10	1.21 ± 0.25	1.1	1	1.8
Cadmium	< 0.1	µg/L	10	1			< 0.1	0.13
Chromium	< 0.5	µg/L	10	0				< 0.5
Cobalt	< 0.1	µg/L	10	0				< 0.1
Copper	< 0.1	µg/L	10	10	0.47 ± 0.79	0.2	0.2	2.7
Iron	< 1	µg/L	10	2			< 1	1
Lead	< 0.1	µg/L	10	0				< 0.1
Manganese	< 1	µg/L	10	0				< 1
Nickel	< 0.5	µg/L	10	1			< 0.5	0.5
Zinc	< 1	µg/L	10	1			< 1	1.4
Mercury	< 0.05	µg/L	10	1			< 0.05	0.07
			Bottom					
TSS	< 0.5	mg/L	10	3	2.17 ± 1.93	< 0.5	< 0.5	4.4
Arsenic	< 0.1	µg/L	10	10	1.42 ± 0.26	1.4	1.1	1.9
Cadmium	< 0.1	µg/L	10	0				< 0.1
Chromium	< 0.5	µg/L	10	0				< 0.5
Cobalt	< 0.1	µg/L	10	0				< 0.1
Copper	< 0.1	µg/L	10	10	0.19 ± 0.03	0.2	0.1	0.2
Iron	< 1	µg/L	10	0				< 1
Lead	< 0.1	µg/L	10	0				< 0.1
Manganese	< 1	µg/L	10	0				< 1
Nickel	< 0.5	µg/L	10	0				< 0.5
Zinc	< 1	µg/L	10	0				< 1
Mercury	< 0.05	µg/L	10	0				< 0.05

Source: Petro-Canada 1998.
* Limit of Quantitation (LOQ): The constituent concentration that produces a signal sufficiently greater than the blank that can be detected with the specified limits by laboratories during routine operating conditions. Also referred to as Estimated Quantitation Limit (EQL).

Table 2.8–2 Trace Metal Concentrations in Seawater from the Grand Banks and Terra Nova Oilfield Site

Trace Metal	Grand Banks			Terra Nova Oilfield		
	LOQ* (µg/kg)	Concentration March (µg/kg)	Concentration November (µg/kg)	LOQ* (µg/L)	Surface Max. Detected (µg/L)	Bottom Max. Detected (µg/L)
Arsenic (As)	0.001	1.89	1.89	< 0.1	1.7	1.9
Cadmium (Cd)	0.04	0.20	0.26	< 0.1	< 0.1	< 0.1
Chromium (Cr)	0.004	0.31	0.37	< 0.5	< 0.5	< 0.5
Copper (Cu)	0.04	1.85	1.97	< 0.1	0.6	0.2
Iron (Fe)	0.037	3.50	1.40	< 1.0	< 1.0	< 1.0
Lead (Pb)	0.028	0.39	0.41	< 0.1	< 0.1	< 0.1
Mercury (Hg)	0.001	0.004	0.002	< 0.05	< 0.05	< 0.05
Molybdenum (Md)	--	0.086	0.460	--	-	-
Nickel (Ni)	0.025	1.36	0.91	< 0.5	< 0.5	< 0.5
Vanadium (Va)	0.005	0.16	0.13	--	-	-
Zinc (Zn)	--	3.79	2.01	< 1.0	< 1.0	< 1.0

Source:

[1] Data for Grand Banks is from MacKnight et al. (1981) in Mobil (1985); concentrations are means from five stations.

[2] Data for Terra Nova Oilfield is from Petro-Canada (1998) and cites the maximum concentration detected. Water samples were collected between 24 September and 7 October 1997.

* Limit of Quantitation (LOQ): The constituent concentration that produces a signal sufficiently greater than the blank that can be detected with the specified limits by laboratories during routine operating conditions. Also referred to as Estimated Quantitation Limit (EQL).

At the Terra Nova site, the only metals detected in the water samples were arsenic and copper (Table 2.8-1 and 2.8-2). All other metals were below detection limits (see LOQs given in tables). Statistical analysis of the data by Petro-Canada (1998) showed that arsenic concentrations differed significantly among stations and depths ($p<0.001$), with concentrations increasing with depth (RBC ANOVA). Copper concentrations differed among depths ($p=0.009$) but not stations ($p=0.18$) (non-parametric Friedman's Test). Median copper concentrations decreased with depth, the opposite of the trend observed for arsenic. With the exception of one outlier (Cu-2.7 mg/L), concentrations of both metals varied little among stations at any depth (Petro-Canada 1998).

2.8.1.5 Hydrocarbons

Polycyclic aromatic hydrocarbon (PAH) concentrations for seawater samples collected at the Terra Nova Oilfield site (Petro-Canada 1998) are summarized in Table 2.8-3. PAH levels were below detection limits in water column samples; however, other hydrocarbons were detected. A study by Levy (1983) on the Grand Banks documented the background total hydrocarbon (C_6-C_{32}) concentration in the water column as 0.17 µg/L and the background level for the surface water as 28.9 µg/L. The primary source of the hydrocarbons was suggested to be from atmospheric fallout of aromatic compounds rather than from point-source emissions dispersed by oceanographic processes. It was noted (Levy 1986) that the background extractable petroleum hydrocarbons (C_{11}-C_{32}) in the water columns throughout the East Coast of Canada are well below the concentrations known to have toxic or sublethal effects on marine life.

2.8.2 Sediment Chemistry

Data relating to sediment chemistry on the Grand Banks are limited to several comprehensive studies performed by Mobil (Mobil 1985; HMDC 1995) and Terra Nova (Petro-Canada 1998). These baseline studies are useful because they provide a general overview of the existing conditions on the Grand Banks.

2.8.2.1 Particle Size

Sediments on the Grand Banks are generally homogeneous, both physically and chemically. During the baseline characterization of the Terra Nova site, sidescan sonar was used to determine the composition of the seafloor. Within the study area the seabed was homogenous on a regional scale and composed of sand and gravel. On a smaller scale, the sands were distributed in poorly organized large-scale low amplitude bedforms (sand ridges and sand waves) superimposed on a coarser (sand with scattered gravel and cobbles) substrate (JWEL 1998). Particle size analyses conducted during the same study indicate that the substrate is 91.35 percent sand, 6.75 percent gravel, 0.84 percent silt and 1.06 percent clay. From data for three years of study for the Hibernia project, the bottom type was found to be similar in particle composition: 6.1 percent gravel, 92.3 percent sand, 0.27 percent silt, and 1.36 percent clay. Barrie and Collins (1989) determined that substrates at depths greater than 110 m are sandy with a grain size of about 0.2 mm, whereas substrates at depths less than 100 m are sandy with a grain size of 0.35 mm and interspersed with gravel (Barrie and Collins, 1989).

Table 2.8–3 Summary Statistics for Water Chemistry Hydrocarbons from the Terra Nova Oilfield Site

Variables	LOQ*	Units	Bottom Depth				Middle Depth			Surface Depth		
			Number of Samples	Number of Samples > LOQ	Max	Min	Number of Samples	Number of Samples > LOQ	Max	Number of Samples	Number of Samples > LOQ	Max
Naphthalene	< 0.05	µg/L	10	0	< 0.05		10	0	< 0.05	10	0	< 0.05
Perylene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
1-Methylnaphthalene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
2-Methylnaphthalene	< 0.02	µg/L	10	0	< 0.02		10	0	< 0.02	10	0	< 0.02
Acenaphthylene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Acenaphthene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Fluorene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Phenanthrene	< 0.01	µg/L	10	1	0.011	< 0.01	10	0	< 0.01	10	0	< 0.01
Anthracene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Fluoranthene	< 0.01	µg/L	10	1	0.02	< 0.02	10	0	< 0.01	10	0	< 0.01
Pyrene	< 0.01	µg/L	10	1	0.015	< 0.015	10	0	< 0.01	10	0	< 0.01
Benz(a)anthracene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Chrysene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Benzo(b)fluoranthene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Benzo(k)fluoranthene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Benzo(a)pyrene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Indeno(1,2,3-cd)pyrene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Dibenz(a,h)anthracene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Benzo(g,h,i)perylene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
1-Chloronaphthalene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
2-Chloronaphthalene	< 0.01	µg/L	10	0	< 0.01		10	0	< 0.01	10	0	< 0.01
Oil & Grease	< 1	mg/L	10	0	< 1		10	0	< 1	10	0	< 1
Vegetable Oil & Grease	< 1	mg/L	10	0	< 1		10	0	< 1	10	0	< 1
Mineral Oil & Grease	< 1	mg/L	10	0	< 1		10	0	< 1	10	0	< 1

Source: Petro-Canada 1998.

* Limit of Quantitation (LOQ): The constituent concentration that produces a signal sufficiently greater than the blank that can be detected with the specified limits by laboratories during routine operating conditions. Also referred to as Estimated Quantitation Limit (EQL).

2.8.2.2 Trace Metals

There have been few studies to date to assess the trace metal composition of Grand Banks sediments. MacKnight et al. (1981) summarized sediment trace metal compositions from several 'non-polluted' sites and found that in pristine areas away from anthropogenic input, concentrations of trace elements are low. Findings by MacKnight et al. (1981), as well as baseline results from Hibernia (HMDC 1995) and Terra Nova (Petro-Canada 1998) are summarized in Table 2.8-4. Note that a comparison has been made with CCME Interim Marine Sediment Quality Guidelines (CCME 1999). Trace metals occur naturally in marine sediments (Stumm and Morgan 1981 in Petro-Canada 1998) and there are naturally occurring differences between nearshore and offshore environments.

Table 2.8–4 Typical Trace Metal Concentrations in Marine Sediments Compared with CCME Interim Sediment Quality Guidelines

Parameter (mg/kg)	Placentia Bay[1]	Bay of Fundy[1]	Upper St. Lawrence[1]	Hibernia Baseline[2]	Terra Nova Baseline[3]	CCME Guidelines[4]
Aluminium					6,360	
Arsenic		9	6	1.7		7.24
Barium				161	130	
Cadmium		0.24	0.26	0.1		0.7
Chromium	53	73	92	4	3	52.3
Copper	34	19	36	2	2	18.7
Iron				2,134	1,531	
Lead	32	30	34	4	2	30.2
Lithium				2		
Manganese					45	
Nickel	41	22	37		2	
Selenium					2	
Strontium					48	
Thallium					.1	
Tin					4	
Uranium					0.2	
Vanadium		95	97		5	
Zinc	80	77	185	5	7	124

Source: [1] = Adapted from MacKnight et al. 1981.
[2] = HMDC 1995.
[3] = Petro-Canada 1998.
[4] = CCME 1999.

Baseline sediment chemistry results of detectable variables for the Hibernia (HMDC 1995) and Terra Nova (Petro-Canada 1998) sites are provided in Table 2.8-5. Chromium, lead and zinc results were similar for both sites. Barium and iron results at the Terra Nova site occurred in the lower part of the range as compared to the Hibernia results (Petro-Canada 1998).

Table 2.8–5 Comparison of Sediment Chemistry Variables Between the Terra Nova and Hibernia Sites

Metal	Concentration (mg/kg)	
	Terra Nova	**Hibernia**
Barium	70-280	60-450
Chromium	2-5	2.3-8.5
Iron	870-3,400	700-6,100
Lead	1.1-4.8	2.3-5.4
Zinc	5-12	2-9
Source: Petro-Canada 1998.		

2.8.2.3 Hydrocarbons

Hydrocarbons are ubiquitous in marine sediments and are commonly found in marine phytoplankton (Parsons and Takahashi 1973). Studies by MacKnight et al. (1981) and Levy (1983) indicate that hydrocarbon concentrations in marine sediments increase near industrial centres. On the Grand Banks, hydrocarbon levels are generally at very low background concentrations. In both the Hibernia (HMDC 1995) and Terra Nova (Petro-Canada 1998) baseline studies, no PAHs were detected above the LOQ in any sediment sample. However, saturated hydrocarbons (alkanes) have been detected in sediments on the Grand Banks (Table 2.8-6).

Table 2.8–6 Total Saturated Hydrocarbon (Alkanes) Concentrations in Marine Sediments

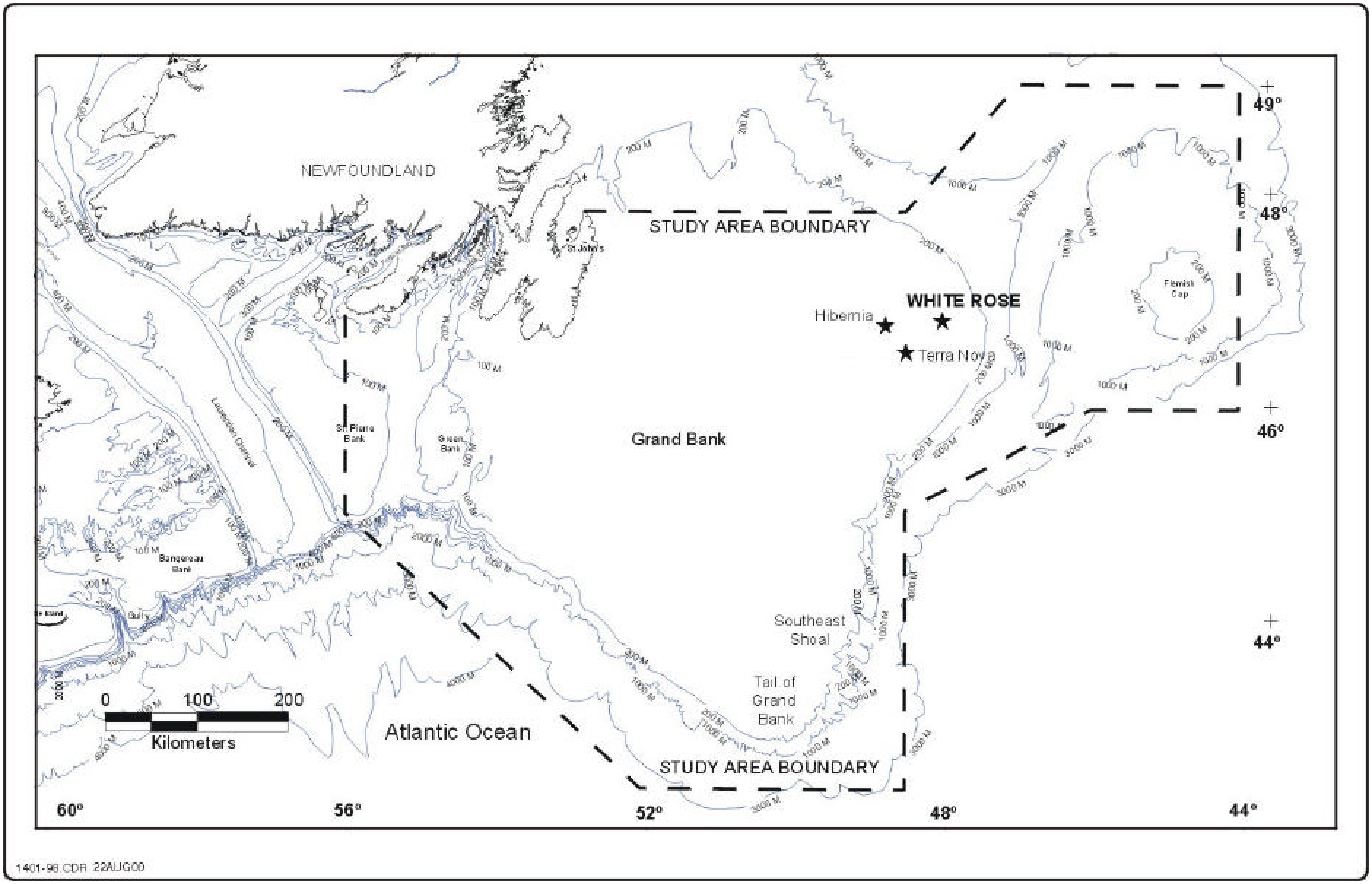
Area	Concentration (mg/kg)	Source
Grand Banks	0 - 4.7	MacKnight et al. (1981)
Grand Banks	0 - 7.3	Levy (1983)
Scotian Shelf	0.01 - 2.3	Keizer et al. (1978)
North Sea	1.0 - 26.0	Ward et al. (1980)
Coastal Newfoundland	1.0 - 25.0	Keizer (1971)
Source: Mobil 1985.		

3 REGIONAL SETTING (BIOLOGICAL ENVIRONMENT)

For the purposes of this part of the assessment, the regional study area is considered to be the Grand Banks ecosystem, as defined in the Hibernia EIS and the Terra Nova Development EIS (Figure 3-1). This ecosystem has been described in detail in the Hibernia EIS from broad scale studies in the early 1980s by Mobil (1985). Since that time, a number of environmental and human-induced changes have occurred that affected the Grand Banks ecosystem, as described in the Terra Nova Development EIS (Petro-Canada 1996). These changes have included the collapse of many fish populations, primarily due to overfishing, resulting in the closure of many fishing areas. Water mass changes have also occurred, resulting in changes in abundance and distribution of many species. There has been an increase in the harvests of other normally-less-fished species such as crab, shrimp, scallops, and clams. All of these factors have contributed to the regional context upon which this description is based.

The Grand Banks ecosystem is a complex and ever-changing system driven by numerous physical, chemical, biological, and human factors. The following brief description is intended to give the reader a general overview of some of the important ecological relationships on the Grand Banks that may affect commercially important fish, the fishery, marine birds and mammals. The ecosystem section is followed by more detailed descriptions of important components of the ecosystem, with emphasis on recent research. A detailed assessment of the commercial fishery is given in the SEIS (Part Two). It is clear that all levels of the ecosystem have likely been affected by the environmental and fisheries changes that have occurred over the last 10 to 15 years.

Figure 3-1 White Rose EIS Regional Study Area



3.1 GRAND BANKS ECOSYSTEM OVERVIEW

3.1.1 Plankton

Plankton refers to those organisms that more or less drift with water currents. Plankton includes microorganisms, algae, juvenile and adult invertebrates, and many species of fish eggs and larvae. Many planktonic organisms are capable of vertical migration within the water column in response to light and other environmental factors such as water temperature. Their distribution and abundance is determined by oceanographic conditions and season. In the North Atlantic, plankton abundance typically peaks in the spring, with a lesser peak in the fall. Plankton often occurs in aggregations caused by oceanographic conditions such as vertical or horizontal fronts or behaviours that create 'swarms.' These aggregation are often exploited by feeding fish, sea birds, baleen whales and other predators.

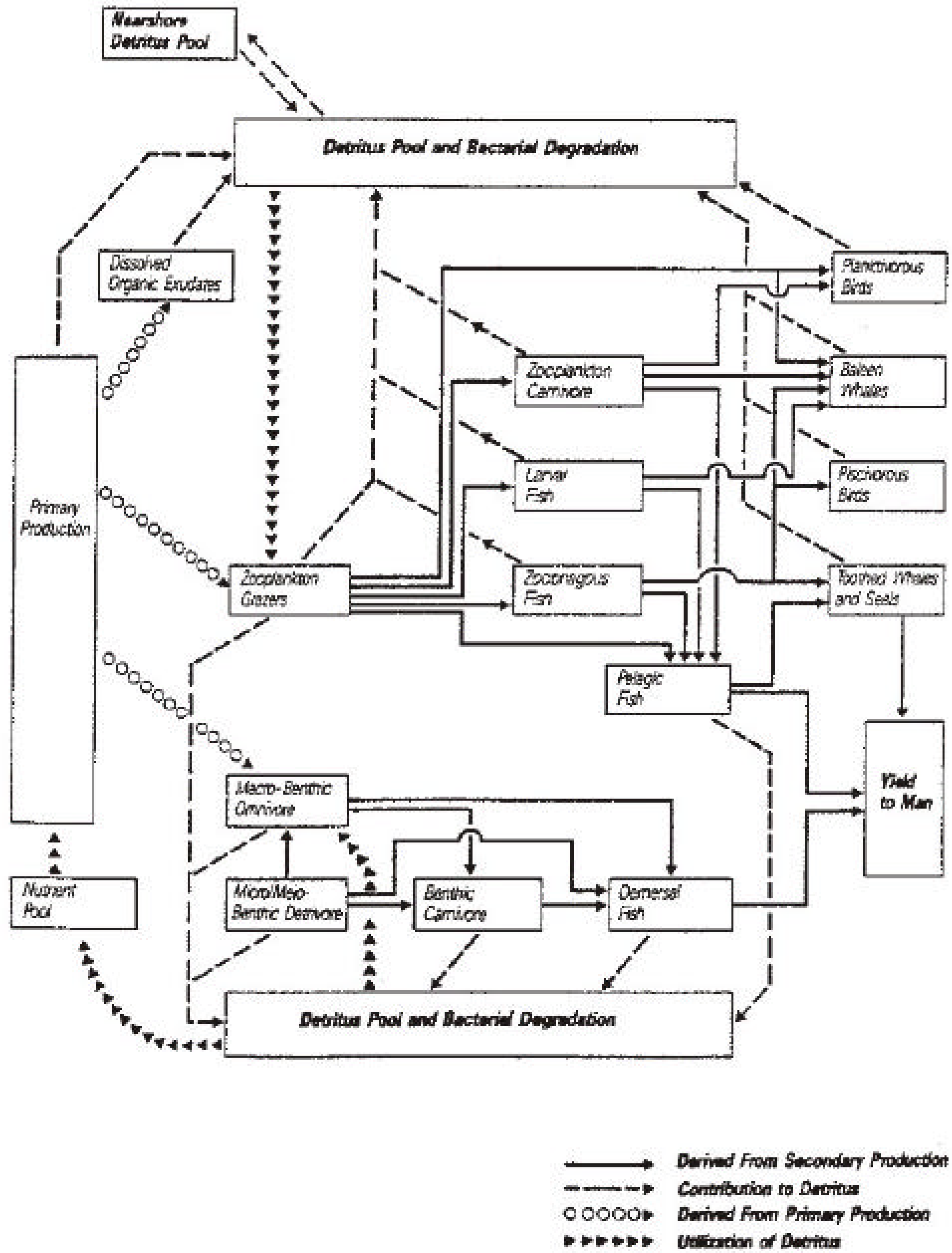
On the Grand Banks, the conversion of water and carbon dioxide into organic matter using sunlight (primary production) is accomplished mostly by phytoplankton in the upper 50 m or so of the water column. Important nutrients used by the phytoplankton during this process include various forms of nitrogen, silicon and phosphorous. Nutrients are recycled into the upper water column by upwelling, microbial activity, and animal excretion. The resulting biomass forms the base of the food web that supports higher life forms. Important energy pathways on the Grand Banks are illustrated in Figure 3.1-1.

Zooplankton play key roles in the world's oceans. Herbivorous species such as copepods feed on phytoplankton and in turn, are fed upon by predacious invertebrates, fish, birds and marine mammals. Their grazing on phytoplankton provides a critical pathway for nutrient regeneration, as well as influences phytoplankton species composition and biomass. Further up the food chain, invertebrate zooplankton such as young copepods can increase fish abundance because copepods are an important food source for young fish. Conversely, predacious zooplankton species such as jellyfish can decrease the abundance of fish by predation upon fish eggs and larvae.

Recent research on the Grand Banks and Flemish Cap have provided further evidence of the importance of invertebrate zooplankton to the ecosystem. Plankton grazing experiments on the Southeast shoal have demonstrated the importance of micro-zooplankton in limiting phytoplankton and bacterial populations (Paranjape 1990).

The Anderson (1990) Flemish Cap work supported the hypothesis of Runge (1988) that copepods act as a direct link between phytoplankton and fisheries variability in temperate marine ecosystems dominated by larger copepods. On the other hand, Myers et al. (1994) suggest that there is no obvious evidence of this in the continuous plankton recording (CPR) data.

Figure 3.1–1 Energy Flow Pathways in the Grand Banks-Flemish Cap Ecosystem



Source: adapted from Walsh (1981) in Mobil (1985)

1401-69.CDR 23JUN00 Figure 3.1-1

Copepods, mainly *Calanus finmarchicus*, *Calanus hyperboreus*, and *Metridia longa*; euphausiids, mostly *Thysanoessa raschii*, but also some *Meganyctiphanes norvegica*; and juvenile sandeels and capelin (*Mallotus villosus*) form the bulk of the capelin's diet on the Grand Banks (Gerasimova 1994). The slopes to the north and northeast of White Rose have been reported to be important feeding areas for immature capelin in spring (Campbell and Winters 1973; Jangaard 1974). Copepods are the most important food item for capelin in NAFO Division 3L (the White Rose area) (Gerasimova 1994).

3.1.2 Benthos

Benthos refers to plants and animals that live in or on the sea bottom. The group is very diverse and includes attached micro- and macro-algae, invertebrates such as polychaete worms, molluscs and crustaceans. Commercially important members include clam, scallop, lobster, shrimp and crab. Some species of fish are associated with the sea floor and may use the substrate for cover, feeding and egg laying. The composition of the benthic community is highly related to substrate type and water depth.

Benthic animals have a variety of feeding behaviours, including filtering, scraping, boring, scavenging, engulfing and seizing. They form an important food resource for many species of fish, including flatfish and cod.

Changing conditions on the Grand Banks over the last 10 years have probably affected the benthic community to some extent. Changing oceanographic conditions, if severe enough, could affect distributions. Mortality rates have decreased with the decrease in bottom trawler activity but this may be offset by increased predation.

3.1.3 Fish

Both pelagic fish (capelin, mackerel and tuna, etc.) and groundfish (skate, flatfish and cod, etc.) fish species that occur in the White Rose area of the Grand Banks are not unique and occur in many other parts of the Grand Banks. A list of commercially important species and their common food items is contained in Section 3.8. Fish are important not only as food for humans, but also ecologically as predators and food for other species.

There appears to have been a shift in the species composition on the Grand Banks, with a decrease in many species in addition to the much-publicized northern cod (Gomes 1993). This is discussed in more detail in Section 3.8.2.

3.1.4 Marine-Related Birds and Mammals

Marine birds and mammals are important predators on zooplankton, benthos and fish. Major feeding relationships are shown in Table 3.1-1. They in turn serve as food for other predators and recycle nutrients into the upper water column through excretion.

Table 3.1–1 Feeding Relationships of Important Marine-Related Birds and Marine Mammals of the Study Area

Food	Birds																Marine Mammals									
	Pursuit Divers					Plunging		Surface Feeders						Klepto-Parasites	Coastal Birds		Baleen Whales				Toothed Whales					Seals
	Dovekies	Murres	Puffins	Razorbills	Black Guillemots	Shearwaters	Gannets	Fulmars	Storm-Petrels	Phalaropes	Gulls	Kittiwakes	Terns	Jaegars, Skuas	Waterfowl	Cormorants, Loons, Grebes	Humpback	Minke	Blue	Fin, Sei	Pilot	Sperm	Killer	Northern Bottlenose	Porpoises, Dolphins	Seals
Polychaetes, Nematodes								X			X		X		X											
Gastropods											X		X													
Bivalves											X	X	X		X											
Cephalopods						X	X	X	X		X	X				X		X			X	X	X	X	X	X
Sea Urchins											X															
Sand Dollars											X															
Sea Stars											X													X		
Sea Cucumbers																								X		
Copepods	X							X	X	X			X					X	X	X						
Mysids/ Euphausiids	X	X				X		X	X	X			X				X	X	X	X					X	X
Hyperiids	X							X	X									X	X							
Amphipods. Isopods	X	X							X		X		X		X											X
Decapods, Crustaceans									X				X		X											X
Pandalus		X																								X
Cancer																										X
Insects											X				X											
Misc. Small Invertebrates			X									X														
Algae															X											
Small Fish Larvae			X			X			X					X		X									X	
Fish Eggs															X											
Redfish																						X		X		
Cod			X				X		X		X					X	X	X		X	X			X	X	X
Flounders																X					X					X
Hake																X									X	X
Sand Lance		X		X	X	X					X	X		X			X			X					X	X
Pout, Gunnels					X																				X	
Tomcod					X						X															

Food	Birds																Marine Mammals									
	Pursuit Divers					Plunging		Surface Feeders						Klepto-Parasites	Coastal Birds		Baleen Whales				Toothed Whales					Seals
	Dovekies	Murres	Puffins	Razorbills	Black Guillemots	Shearwaters	Gannets	Fulmars	Storm-Petrels	Phalaropes	Gulls	Kittiwakes	Terns	Jaegars, Skuas	Waterfowl	Cormorants, Loons, Grebes	Humpback	Minke	Blue	Fin, Sei	Pilot	Sperm	Killer	Northern Bottlenose	Porpoises, Dolphins	Seals
Skate																							X	X		X
Haddock																										
Capelin		X	X	X	X		X				X	X		X		X	X	X		X						X
Herring							X				X		X		X	X	X	X		X				X	X	X
Mackerel							X														X				X	X
Lanternfish									X																	
Misc. Fish					X				X				X		X	X		X				X			X	X
Offal						X		X	X		X			X												
Vegetation, Seeds, Berries											X															
Bird Eggs, Young											X		X		X											
Seals, Birds																							X			

Source: Petro-Canada 1995

3.2 PHYTOPLANKTON

In the marine ecosystem, primary production, which is the conversion of water and carbon dioxide into organic matter in the presence of sunlight, is accomplished primarily by two groups of plants: (1) microscopic phytoplankton free-floating within the water column; and (2) seaweeds (macrophytes) and vascular plants attached to the bottom substrate. A third group, microscopic algae that live on the surface of macrophytes and on bottom sediments, can be important primary producers as well, and can provide rich grazing in coastal areas. This section focussed on phytoplankton; macrophytes and other attached algae are described in Section 3.4 (Benthos).

A description of the phytoplankton of the study area has been summarized in the Terra Nova Development EIS based on Mobil (1985) and the results of the Mobil-sponsored cruises of 1980-81 described by Hollibaugh (1981) and Hollibaugh and Booth (1981). This section contains a brief synopsis of that material with emphasis on quantitative data that can be used for effects assessment. Research conducted after the Terra Nova EIS (Petro-Canada 1995) is also highlighted. The large scale processes and trends concerning phytoplankton from previous studies are at least generally applicable to the White Rose area.

Phytoplankton are responsible for most of the primary production in the open ocean areas of the Grand Banks, as it is worldwide. In order to photosynthesize, cells must remain in the upper well-lit portion of the water column known as the euphotic zone. Phytoplankton lack the ability of large-scale movement, thus, their distribution is heavily dependent on physical processes. Their growth and abundance is highly seasonal and dependent on the amount of sunlight, nutrients (primarily nitrates, phosphates and silicates) and stability of the water column.

In the northwestern Atlantic, the highest standing crops (as measured by chlorophyll *a* concentrations or cell counts) and growth rates (as measured by the amount of primary production) are usually found in the spring. This is known as the spring bloom, and is generally dominated by diatoms. After the spring bloom the standing crop and growth rates drop back to near-minimal levels and then rise again to a second generally smaller peak in late summer or early fall. This fall bloom is generally much smaller than the spring bloom and is dominated by dinoflagellates and other microflagellates. After the fall bloom, standing crop and production drop to a winter minimum.

The annual seasonal cycles of chlorophyll and primary production for the study area, averaged for all areas sampled in the Mobil-sponsored cruises in 1980-81, are shown in Figure 3.2-1. In March, chlorophyll concentrations averaged 24 mg/m^2 and primary production averaged 300 mg carbon (C)/m^2/d. As the season progressed, water column stratification and stabilization intensified and light levels increased. This was accompanied by a rapid increase in standing crop and production to a peak in May, when typical spring bloom diatoms dominated the phytoplankton. The peak average chlorophyll concentration, found in May, was 130 mg/m^2; at the same time production rates averaged 1,710 mg C/m^2/d. The spring bloom quickly dissipated and from July to September average chlorophyll concentrations varied between 11 and 18 mg/m^2, while production rates varied between 238 and 299 mg C/m^2/d. Chlorophyll concentrations were slightly higher in November (average of 31 mg/m^2) but the full fall bloom may have been missed by not sampling in October. The standing crop then dropped to its winter minimum (average chlorophyll concentration of 12 mg/m^2 and production of 72 mg C/m^2/d in January).

The vertical distribution of chlorophyll and nitrate, the most limiting nutrient, are shown for the northeast Grand Banks in Figure 3.2-2, based on data collected during the Mobil-sponsored cruises. In the winter months, the standing crop, as measured by chlorophyll concentrations and nitrate, was distributed fairly evenly throughout the water column. At the height of the spring bloom in May, chlorophyll levels were high in the surface waters, where nitrate had become depleted. During the summer, standing crop was again more evenly distributed throughout the water column, while nitrate levels remained depleted in the surface waters. With the breakdown of stratification in the fall, nitrate levels were replenished in the surface waters while chlorophyll levels remained low.

Figure 3.2–1 Mean 0-50 m Phytoplankton Chlorophyll Concentration and Primary Production Rate on the Grand Banks: 1980-1981

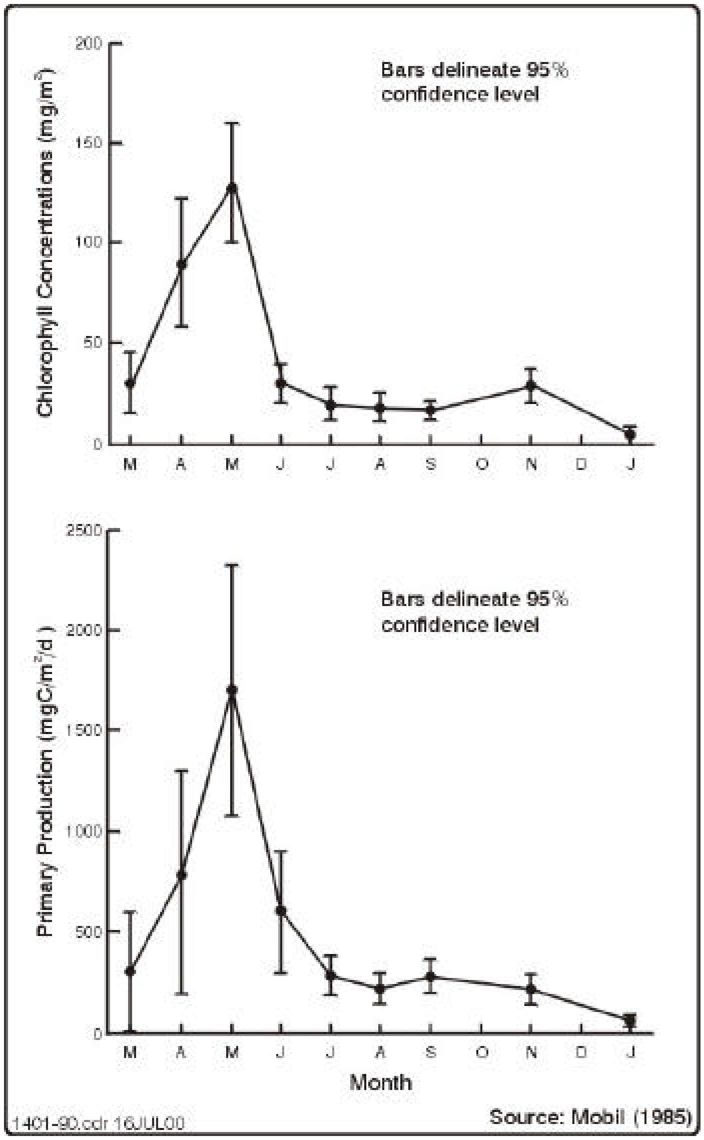
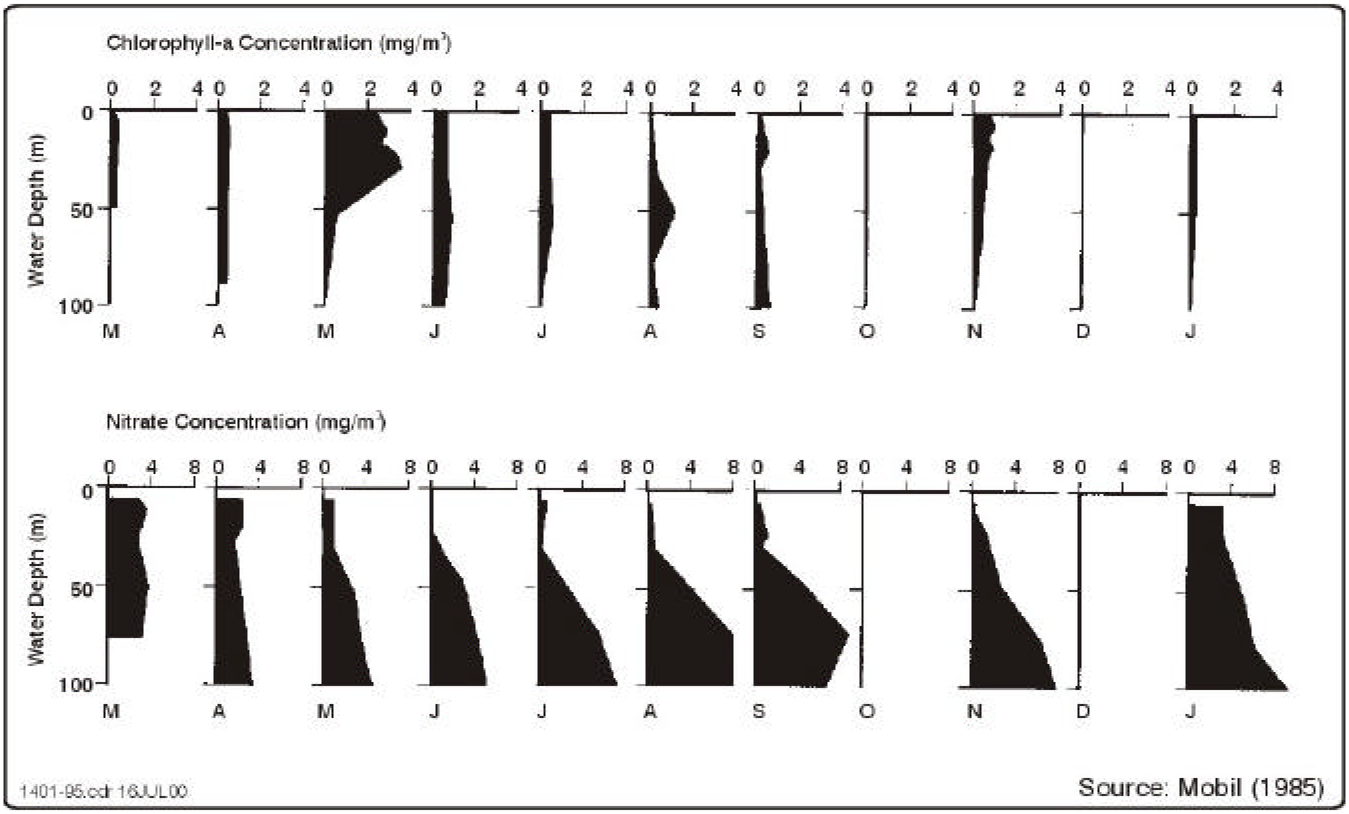


Figure 3.2–2 Distribution of Chlorophyll-a and Nitrate in the Hibernia Area



The results of the Mobil-sponsored cruises clearly showed geographic variations in phytoplankton biomass and productivity. In particular, productivity appeared to be high along the shelf break of the Grand Bank in a frontal zone. It was also high in the Avalon Channel, in a patch south of the Avalon Peninsula, and to the west of St. Pierre Bank.

Subsequent research by Anderson and Gardner (1986) confirmed that the shelf break was an area of high productivity. Field studies in 1986, 1988 and 1990 by Pomeroy et al. (1991) demonstrated the Grand Banks bloom can be highly variable in length and size, depending on weather conditions, and can be short-lived and intense or drawn out over a two or three-month period between March and June. There is evidence that very small phytoplankton species, the "ultraplankton", play a much larger role in the spring bloom than was previously thought (Murphy and Haugen 1985; Li et al. 1993). Ultraplankton are cells < 5 to 10 µm, and are composed of a diverse group of plant-like bacteria and bacteria-like plants. Brown and Yoder (1993), using satellite imagery, have observed large area blooms of “ultraplankton” over the Grand Banks, and speculated that these blooms seasonally impact the region's carbon and sulphur cycles. Prasad and Haedrich (1993), again using satellite imagery, demonstrated the patchiness in chlorophyll concentrations over the Grand Banks. Interestingly, they found small patches of elevated chlorophyll concentration in February before the spring bloom off the Avalon Channel and in Bonavista and Trinity bays, and speculated that these may have indicated production that sustains winter fisheries in these areas.

New information since the Terra Nova EIS includes DFO surveys reported in Anderson and Dalley (1997). Phytoplankton data were collected during late summer pelagic surveys in 1994 and 1995 in a broad geographical area from the southern Labrador Shelf to the Southern Grand Bank. Chlorophyll data were collected as part of surveys directed at pre-recruit Atlantic cod (*Gadus morhua*) and capelin (*Mallotus villosus*). Phytoplankton biomass was usually highest at and below the pycnocline (that part of the water column with the steepest density gradient and hence the highest degree of stability). Peak chlorophyll depths each year ranged from 10 to 70 m, averaging 36 m in 1994 and 34 m in 1995 throughout the survey area. Surface chlorophyll values were typically low, averaging less than 1.0 mg/m^3 each year. Overall chlorophyll values in 1994 and 1995 averaged 3.3 mg/m^3 and 3.0 mg/m^3, respectively. Peak chlorophyll values (approximately 10 mg/m^3) almost always occurred over the deep water channels (> 400 m) on the Northeast Newfoundland Shelf, north of the Grand Banks. Other chlorophyll data were collected during similar surveys between 1996 and 1999, but are unavailable at this time (J. Anderson, pers. comm.).

3.3 INVERTEBRATE ZOOPLANKTON

Zooplankton are weak-swimming or floating animals that more or less drift with the ocean currents, although some species are capable of extensive vertical migrations in the water column. The group is composed of a wide variety of organisms (from protozoans to vertebrates), with sizes ranging from tiny microbes to jellyfish whose tentacles may extend tens of metres. Many bottom-dwelling invertebrates (for example, crabs) and groundfish have planktonic eggs and/or larvae. Zooplankton have varied feeding habits that may involve absorbing nutrients from dissolved organic matter, filtering of large amounts of water, using large mucus nets, stinging or seizing apparatus to trap prey. They are an important component in the ecosystem in nutrient recycling and in the transfer of energy from lower levels, such as phytoplankton, to Valued Ecosystem Components (VECs), such as commercial fish, seabirds and marine mammals.

In predicting the effects of chemical or petroleum hydrocarbon spills on VECs, it is desirable to have selected information on their primary food sources, such as:

- species composition, particularly dominant species;
- abundance and biomass; and
- distribution in time, geographic space and water column.

This section briefly summarizes some relevant aspects of invertebrate zooplankton on the Grand Banks. The background study by Strong (1981) was the major source of relevant information up to the time of the Hibernia EIS (Mobil 1985). The Terra Nova EIS relied on these works plus Anderson and Gardner (1986) on communities and water masses, Anderson (1990) on seasonal development, Paranjape (1990) on microzooplankton herbivory, Gerasimova (1994) on capelin feeding and Myers et al. (1994) on distribution and abundance. Relevant information from these studies is presented and constraints discussed in light of applicability to White Rose.

Anderson and Gardner (1986) and Paranjape (1990) conducted work on the Southeast Shoal, a physically unique area that is probably not directly applicable to the White Rose area. The plankton community over the Southeast Shoal is largely controlled by a gyre. Seasonal zooplankton information is also available for the Flemish Cap, another physically unique area not directly comparable to White Rose (Anderson 1990). The broad scale studies of Gerasimova (1994) and Myers et al. (1994) are generally applicable to White Rose. The CPR data contained in Myers et al. (1994) is of particular interest because it is derived from a large number of samples (17,000) over a long period of time (1959 to 1992). However, it suffers from somewhat sporadic coverage, particularly in the White Rose region of the Grand Banks, presumably because White Rose is somewhat off the normal shipping routes.

Since the Terra Nova EIS, there have been several Canadian Stock Assessment Secretariat Research Documents describing results of broad-scale surveys of the marine pelagic environment (MPE) between 1994 and 1998 (Anderson and Dalley 1997; Anderson et al. 1999; Dalley and Anderson 1997, 1998; Dalley et al. 1999). The broad-scale MPE surveys of temperature, plankton and nekton conducted during the late summer periods of 1994 to 1999 included inshore and offshore waters from southern Labrador to the Southern Grand Bank (NAFO Statistical Divisions 2J3KLNO). However, the ‘Nose' of the Grand Banks was not included in the study area. The easternmost stations on the northern Grand Bank were located west of the White Rose area. Invertebrate zooplankton were included in samples collected during these surveys (Dalley and Anderson 1997, 1998; Dalley et al. 1999). Data are not yet available from the 1999 survey (J. Anderson, pers. comm.).

3.3.1 Species Composition

A total of at least 86 species of invertebrate zooplankton from 11 phyla were collected during the Mobil surveys on the Grand Banks (Strong 1981). In large mesh (333 µm) plankton nets, the Atlantic cold water species *Calanus finmarchicus* (calanoid copepod), was dominant in terms of overall abundance (1 to 1000/m^3). *C. finmarchicus* is the dominant calanoid in the Northwest Atlantic (Akenhead 1980). Other abundant species included the copepods *C. glacialis* and *C. hyperboreus* (two Arctic species that were particularly evident beyond the 200 m isobath and during May and June), *Temora longicornis, Pseudocalanus minutus* and *Centropages harmatus*. Barnacle larvae were very abundant at certain stations and times.

In the small mesh (80 µm) nets, the samples were dominated numerically by the small cyclopoid copepod *Oithona similis* in concentrations often higher than 100,000/$m^{3.}$ Other numerous small-sized species included the cyclopoid *Oncaea minuta* and the hapacticoid copepod *Microsetella norvegica*.

The neuston net (333 µm mesh) sampled the upper 10 cm of the water column. In these collections, the copepods *C. finmarchicus*, *C. glacialis*, *P. minutus*, *T. longicornis*, the amphipod *Parathemisto gaudichaudi*, the larvacean *Frittilaria borealis*, barnacle nauplii and crab zoea dominated at various times and locations.

The CPR data analyzed after the Hibernia EIS confirmed that zooplankton in North Atlantic surface waters are dominated by calanoid copepods (Myers et al. 1994).

Anderson and Gardner (1986), based on samples collected in mid-May 1981 on the eastern boundary of the Southeast Shoal, found shallow water stations were dominated by the ctenephore *Pleurobrachia pileus*, whereas shelf break and deepwater stations were dominated by copepods, primarily late stages of *C. finmarchicus* and *Pseudocalanus* spp. These authors found the highest calanoid copepod biomass to be associated with Labrador Current water at the shelf break. Paranjape (1990) found the micro-zooplankton to be dominated by the oligotrichs of the genera *Lohmanniella* and *Strombidium* during three seasons (April, July and October).

The most extensive data on abundance are contained in Myers et al. (1994). Counts for the 10 m sampling depth are presented for approximately 50 taxa, including approximately 25 invertebrate taxa on a monthly basis. In NAFO Division 3L, which contains White Rose, the highest counts are typically due to copepods, particularly *C. finmarchicus*, *Pseudocalanus* spp., *T. longicornis*, *Acartia* spp., *O. similis*, and a few others. While other groups such as hyperiid amphipods, euphausiids and chaetognaths may not be as abundant as copepods, they may be extremely important in terms of biomass, at least at certain times and locations.

During the MPE surveys in 1994 and 1995 (Anderson and Dalley 1997), copepods dominated the macro-plankton, with *C. finmarchius* dominating the Northern Grand Bank and *Centropages hamatus* dominating the Southern Grand Bank. The seasonal production cycle of *C. finmarchius* was more advanced in the inshore area than on the adjacent shelf. On the Southern Grand Bank, *C. hamatus* was dominated by adult females, which indicated a late summer spawning. While abundances were generally lower on the Grand Banks (100 to 500 m^3) for all species, the peak abundance of *C. hamatus* on the Southeast Shoal was approximately 3,500/m^3. The next most abundant zooplankton species on the Grand Banks were *Temora longicornis*, *Pseudocalanus* spp. and *Limacina helicina* (Anderson and Dalley 1997).

3.3.2 Geographic Distribution

Some of the major factors influencing the temporal and spatial distribution of zooplankton in the North Atlantic are the locations of main overwintering stocks, water currents and temperature (Colebrook 1982).

In general, water circulation in the Grand Banks and Flemish Cap areas is dominated by the cold, southward flowing Labrador Current. The Labrador Current branches near the northern portion of the banks into relatively strong inshore (Avalon Channel) and offshore components. Currents over the banks, other than wind driven surface currents, tend to be weak and variable with a possible anticyclonic gyre on the southeastern area of the banks (Petrie and Anderson 1983). South of the Grand Banks, the southward flow is bounded by and turned eastward by the warm water of the North Atlantic Drift.

Oceanographic ‘fronts,’ boundary zones between adjacent water masses of dissimilar characteristics, may also affect the distribution of zooplankton by concentrating the free-drifting plankton. The Grand Banks may contain the following types of fronts, as defined by Bowman (1978):

- fronts at the edges of western boundary currents;
- shelf break fronts; and
- shallow sea fronts formed around banks and shoals.

Worldwide, such fronts are known to be important feeding areas for fish, birds and mammals and are often exploited by commercial fisheries as well.

Although a number of fronts probably exist in the Grand Banks area and at least several expected ones (shelf break front and a front south of the Grand Banks between the Labrador Current water and the North Atlantic Drift) may be relatively extensive and semi-permanent, no one has clearly demonstrated a ‘concentrating effect’ on zooplankton populations there. This is probably due to a low resolution in sampling design (sampling locations too far apart) rather than a real lack of effect. Most large scale studies in the western North Atlantic (IGY and CPR programs) have shown that total plankton (or at least the dominant species *C. finmarchicus*), as measured by total numbers and/or biomass, is higher on the Grand Banks than in the oceanic water farther offshore (Kusmorskaya 1959; Robinson et al. 1975).

Particular zooplankton species or groups of species can be used to indicate specific water masses. This is more useful than describing species composition relative to fixed geographic points because the planktonic environment is extremely dynamic in the Grand Banks region. Species that may be useful indicators of water types in the study area include *C. glacialis* (water of Arctic origin), *C. finmarchicus* (mixed Arctic and Atlantic water) and *Calanus helgolandicus* (subtropical Atlantic water (Matthews 1969; Jaschnov 1970)). Other indicators have included ctenophores for cold Labrador Current water (Pinhey 1926) and seven species of euphausiids for a variety of water masses near the Grand Banks (Drobysheva 1964).

In general, the zooplankton of Flemish Cap and the Grand Banks is dominated by cold water (Arctic or boreal) species (Pavshtiks et al. 1962; Semenova 1963; Strong 1981, and others). However, warm water species may occur as 'strays'; and Bainbridge (1961) and Pavshtiks et al. (1962) have reported patches of warm water species in late winter just northeast of the Grand Banks; they may enter the area in eddies or counter currents from the North Atlantic Drift.

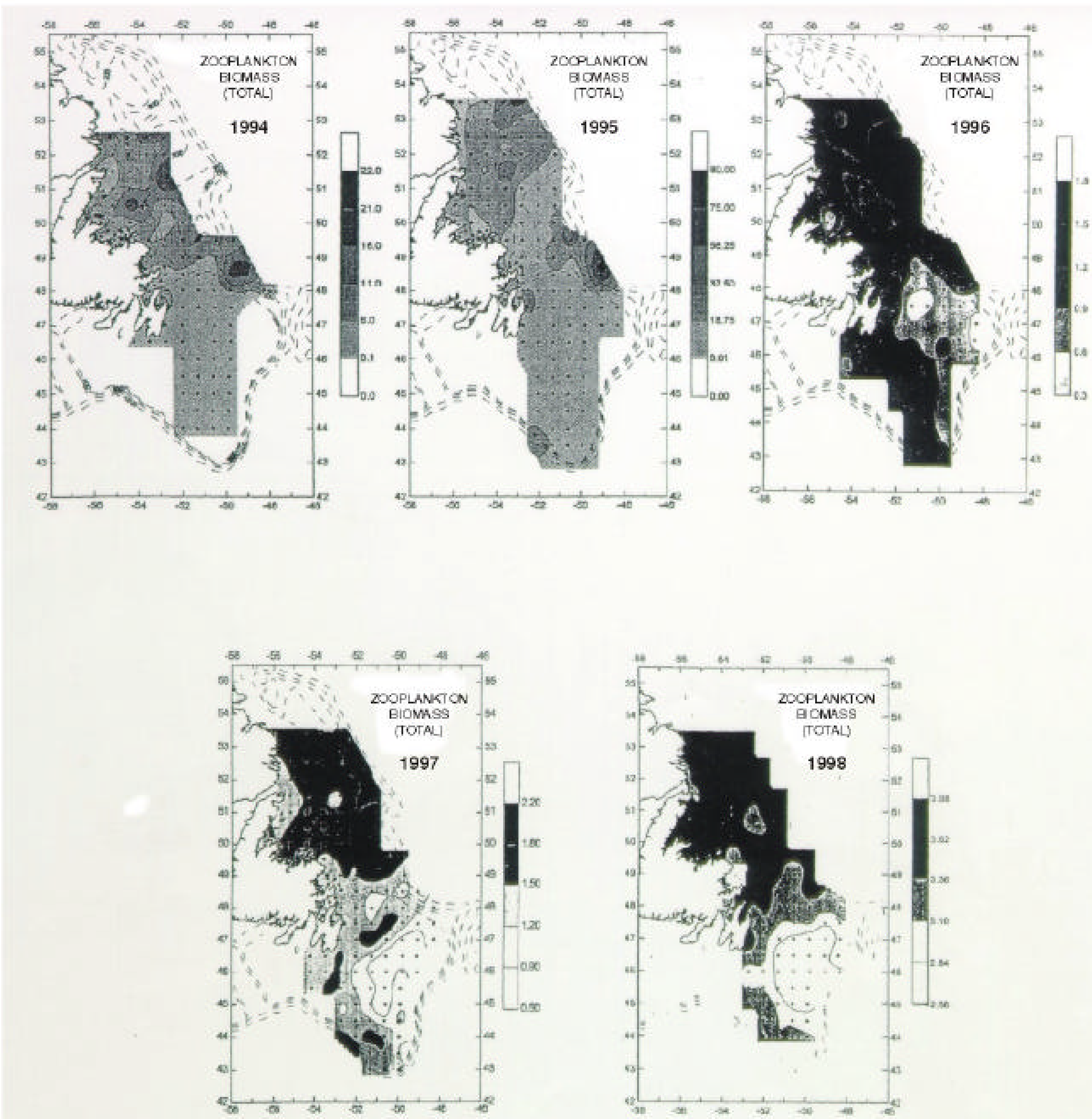
During the year-round (1980-81) zooplankton survey, none of the regions (five representative subareas) examined demonstrated substantial differences in zooplankton biomass, although during the spring, a few stations appeared to have consistently high biomass. These 'high biomass' areas included the northern shelf break, the central portion of the southeast bank and nearshore stations near the Avalon Peninsula (Strong 1981). No species, or groups of species, are reported by Strong (1981) to be more common or unique to specific geographic areas. There was, however, considerable variation between stations.

Variation between stations in abundance and biomass was due primarily to the patchy nature of zooplankton distributions. Zooplankton may be highly aggregated (by 100 to more than 1,000 times the average density of the population as estimated by net sampling) according to Omori and Hamner (1982), due to swarming behaviour of such animals as mysids and euphausiids and others (Omori and Hamner 1982; Sameoto 1983) or physical concentrating mechanisms such as eddies and fronts (Longhurst 1980, 1981; Owen 1981).

The spatial and temporal scale of the sampling design used by Strong (1981) was of too large a scale to adequately document any concentrating effects. Further south, Herman et al. (1981), using continuous sampling equipment, showed a much higher estimated plankton production and copepod abundance at the shelf break front off Nova Scotia than in the shelf and slope waters. It is likely that there is also some shelf break effect at the edges of the Grand Banks; Longhurst (1980) shows the approximate expected position of a semi-permanent front (as composed from several satellite infrared images) and there were 'suggestions' of its presence from the data collected for Mobil (1985). Anderson (1990) reported maximum calanoid copepod spawning, as evidenced by egg and nauplii densities, in the shallow water over the Flemish Cap; however, this author also found evidence of spawning in deep water off the Cap.

Distributions of invertebrate zooplankton biomass sampled during the 1994 to 1998 MPE surveys are presented in Figure 3.3-1. Zooplankton biomass for all three size fractions (< 1 mm, 1 to 2 mm, and > 2 mm), especially for the macro-plankton (> 1 mm), was highest over the Northeast Newfoundland Shelf during the 1994 and 1995 surveys. Biomass tended to be lowest inshore and on the Grand Banks. Zooplankton biomass in 1995 was at least 2.5 times that in 1994 (Anderson and Dalley 1997).

Figure 3.3–1 Distributions of Invertebrate Zooplankton Biomass (mg dry weight/m^3), 1994-1998



1401-27.cdr 23JUN00 Figure 3.3-1

Source: Anderson and Dalley (1997); Dalley and Anderson (1997, 1998); Dalley et al. (1999)

Results of the 1996 survey indicated that the lowest total dry weight biomass of zooplankton occurred on the South Grand Bank. The distribution of biomass of all size fractions showed a general gradient of decreasing weights from north to south, with minimum weights occurring on the eastern Grand Banks. The mean total zooplankton biomass in 1996 was comparable to 1995, both being substantially higher than 1994 (Dalley and Anderson 1997).

Consistent with the results of surveys during the first three years, total zooplankton biomass in 1997 and 1998 was again highest in the north, particularly north of the Grand Banks, and the lowest weights of zooplankton occurred on the eastern Grand Banks (Dalley and Anderson 1998; Dalley et al. 1999). Considering only the Grand Banks, the highest weights of zooplankton were over the western portions of the North Grand Bank and the South Grand Bank. Overall, mean total zooplankton biomass was significantly higher in 1997 and 1998 than in the preceding three years. Zooplankton biomass in 1994 was substantially lower than all four following years (Dalley et al. 1999).

From a statistical perspective, both year and area significantly accounted for zooplankton variability within the study area during 1994 to 1998. Of the two, area had the most effect (Dalley et al. 1999).

3.3.3 Vertical Distribution

Very little information is available concerning the vertical distribution of invertebrate zooplankton on the Grand Banks. The dominant species, *C. finmarchicus,* although found over the Grand Banks during winter, may overwinter in deep water off the banks. Semenova (1963), sampling during early spring, found much higher numbers (36 to 220/m^3) in deep water off the banks and off Flemish Cap, compared to 0 to 16 individuals/m^3 in the shallow waters on the banks. Kusmorskaya (1959) sampled during early spring and late fall with closing nets and found that *C. finmarchicus* was distributed from surface to bottom over the Grand Banks, but was more or less restricted to deep water (200 to 500 m) further east. Kusmorskaya (1959) also found that total plankton was greatest in the upper 200 m near the Grand Banks and that during spring spawning, the highest numbers ('tens of thousands') of *C. finmarchicus* occurred in the upper 50 m.

In general, it is likely that the highest numbers of zooplankton are found in the upper 50 m of the water column, particularly during the spring bloom. This is true for eastern Canadian Arctic waters (Buchanan and Sekerak 1982) and Labrador waters (Buchanan and Browne 1981) and is likely for the Grand Banks, including the White Rose area, which is heavily influenced by the Labrador Current.

Strong's study (1981) was not designed to collect vertical distribution information. However, the data based on surface (neuston) net collections suggest that four species of important copepods (including *C. finmarchicus* and *P. minutus*) were much more (by a factor of six) numerous right at the surface at night than they were during the day. In addition, the surface-dwelling copepod *Anomalocera patersoni* and the amphipods *Parathemisto* spp. appeared to be much more numerous right at the surface (upper 10 cm). This vertical migration by some species (both invertebrates and fish) has been observed for many years. Typically, invertebrate migration involves four phases, mostly in response to light conditions: (1) ascent from day depth, (2) midnight sinking, (3) dawn rise and (4) descent to day depth (LaRow 1976).

There have been no recent studies specifically addressing vertical distribution of invertebrate zooplankton on the Grand Banks. The CPR data are constrained by sampling horizontally at one depth (nominally 10 m but actually 6.7 ±1.7 m; Myers et al. 1994). After analysis of CPR data collected during 1958 to 1992, Hays (1996) suggested that normal diel (twice daily) vertical migration was less marked on the Grand Banks than in the rest of the deepwater northwest Atlantic.

Anderson (1990) provides valuable data on the vertical distribution of copepod eggs and nauplii, (*C. finmarchicus* and 'other copepods') on the Flemish Cap. However, the extrapolation of these data to the White Rose site is constrained by the relatively coarse strata used (≤ 200 m; 201 to 400 m; ≥ 400 m) and by the fact that Flemish Cap is a unique area because of its bathymetry and physical oceanography.

3.3.4 Seasonal and Annual Variability

The dominant seasonal feature of zooplankton populations in the North Atlantic is the massive development of herbivorous species (for example, some copepods, including *C. finmarchicus*) either during the spring phytoplankton bloom or shortly thereafter. Carnivorous species (jelly fish, some amphipods, chaetognaths, etc.) also develop rapidly at this time of abundant food. A lesser fall bloom may also occur in some areas under certain conditions.

Colebrook (1982), in examining CPR data from the North Sea and North Atlantic since 1948 for four phytoplankton and five zooplankton taxa, concluded that seasonal variations appear to be controlled by the distribution of main overwintering stocks, currents and in some instances, temperature control of the rate of population increase.

C. finmarchicus undergoes massive spawning on the Grand Banks during the spring (Kusmorskaya 1959; Pavshtiks et al. 1962). Vladimirskaya (1967), using 810 samples from 194 oceanographic stations in the northwest Atlantic during 1958 to 1961, found the greatest abundance of *C. finmarchicus* (3.5 to 7.5 x $10^5/m^2$) during spring in those areas most influenced by the Labrador Current (northern and northeastern Grand Bank). Mass development seemed to proceed earliest in the warmer water of the southern and eastern Grand Banks. Matthews (1969) also observed this from CPR data. During summer, Vladimirskaya found that *C. finmarchicus* was most abundant on the northeastern Grand Bank (5.0 to 7.0 x $10^5/m^2$) and northeastern Flemish Cap (4.5 x $10^5/m^2$). During early autumn, greatest abundance was on the eastern (3.2 x $10^5/m^2$) and southwestern (1.1 x $10^5/m^2$) slopes of the Grand Banks; during late autumn greatest abundance was on the northern slope. Most were at overwintering depths (greater than 100 m or below 200 to 500 m where possible) by early October (Vladimirskaya 1967). However, care must be used in interpreting Vladimirskaya's results because of the potential for a lack of discrimination between the possible species of *Calanus (C. finmarchicus* vs. *C. glacialis*). Vladimirskaya's (1965) data on total zooplankton biomass are probably of more use in effects prediction than the number of *C. finmarchicus* (Table 3.3-1).

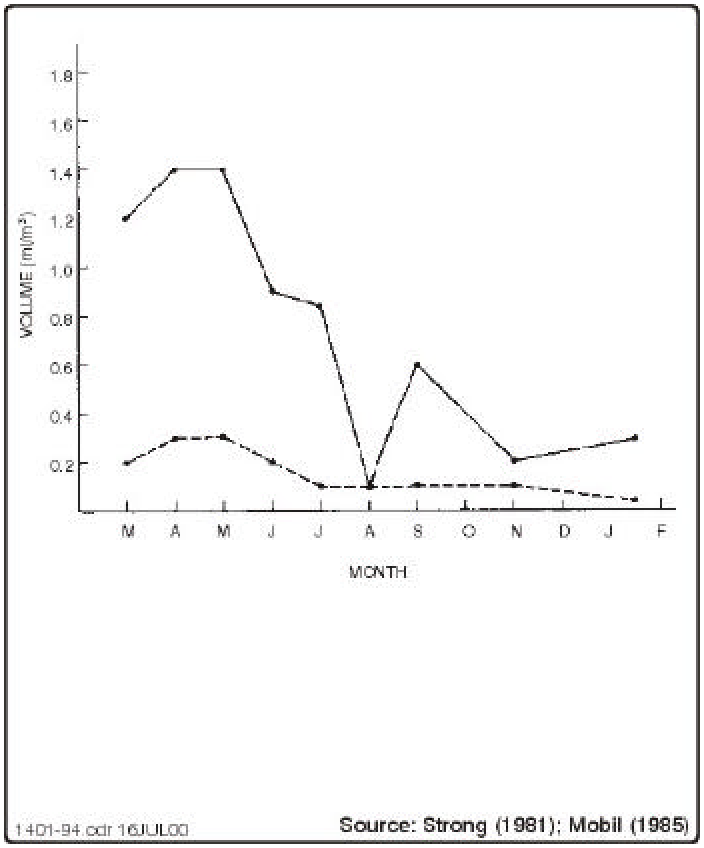
Table 3.3–1 Zooplankton Biomass on the Grand Banks

Season	Depth (m)	Mean Biomass (mg/m^3)
Spring	0-100	130-350
	0-200	Up to 900
Summer	0-100	May exceed 1000
Autumn	0-100	100-300

Source: Vladimirskaya 1965.

Mean total zooplankton biomass (as measured by displacement volumes) on the Grand Banks as determined by Strong (1981) appears to follow the classical pattern of great increases in the spring in conjunction with the spring phytoplankton bloom, a decrease in the summer probably due to predation and overgrazing of phytoplankton, and a slight increase in the fall, possibly as a response to a fall phytoplankton bloom (Figure 3.3-2). In contrast, Kendaris (1980), in an inshore study conducted from April to September, found that although copepod larval stages were greatest during May, total zooplankton abundance was low until August when it increased by a factor of five. Overall, the copepods *P. minutus* and *Oithona nana* dominated the zooplankton, with the copepod *T. longicornis* replacing *O. nana* in September.

Figure 3.3–2 Mean Zooplankton Displacement Volume in the Upper 70 m on the Grand Banks



C. finmarchicus dominates the zooplankton community of Flemish Cap in terms of both abundance and biomass. Times of maximum spawning appear to be controlled by water temperature and occur in mid-April on the Cap. They may be a month earlier on the shelf to the west and south (the White Rose area) (Anderson 1990). Spawning times of *C. finmarchicus* are known to be closely linked to the spring phytoplankton bloom. Maximum numbers of *C. finmarchicus* at the 10 m depth occur in August in NAFO 3L, which includes the White Rose area (Myers et al. 1994).

Peaks in abundance of some other major species at the 10 m depth are shown below (Table 3.3-2).

Table 3.3–2 Seasonal Peaks in Abundance of Major Zooplankton Species on the Grand Banks

Timing	Species
January	*Pleuromamma robusta, Pleuromamma borealis ,Pleuromamma gracilis*
January-February	*Metridia lucens*
March	*Clione limacina*
July	*Eucheata norvegica*
August	*C. finmarchicus, T longicornis, Acartia* spp., *Podon,* spp., *Evadne* spp., *euphausiids*
November	*Oithona* spp., *chaetognaths*

Source: CPR data contained in Myers et al. 1994.

One of the characteristics of plankton communities is their variability in time and space. While plankton is more or less ubiquitous, patchiness in community structure, abundance and biomass may vary on scales from several metres to many kilometres. There also may be considerable interannual variability and this has been recognized by recent researchers. For example, there are numerous examples in Myers et al. (1994) of interannual variability and these authors found a decline over the long term in both diatom and copepod abundances, based on the 1959 to 1992 CPR data. Anderson (1990) found substantial differences among years in the development rates and abundance of *C. finmarchicus*, a dominant species in the study area. Anderson and Gardner (1986) note the interannual variability in abundance of the predatory combjelly *P. pileus*, a potentially important determinant of larval fish abundance. Gerasimova (1994) remarked on the interannual variability in the location of capelin feeding areas on the Grand Banks and a shift from euphausiids to larval fish prey when euphausiids are scarce.

3.4 BENTHOS

3.4.1 Macrophytes and Associated Microscopic Algae

Information on macrophytes is summarized in Mobil (1985) and Petro-Canada (1996). The term "macrophytes" encompasses both large algal species such as kelps, and large vascular plants such as eelgrass. Microscopic algae, often benthic diatoms, are usually found growing on these macrophytic plants and on the bottom substrate where light and other conditions are suitable.

Approximately 300 species of macrophytic algae occur in the coastal zone of the study area. Their spatial distribution is controlled by substrate type (macrophytic algae require solid, stable surfaces for attachment), exposure, depth and light penetration, ice scour and water temperature. The macrophyte zone is highly productive and provides important habitat for many species. Four distinct communities can be identified on the basis of location:

- the community growing in shallow waters and intertidal areas of coastal Newfoundland;
- the community growing in the shallow waters of the Virgin Rocks-Eastern Shoals region;
- coralline algal communities growing in deeper waters to depths of 50 m; and
- communities that have developed as part of the biofouling community on drilling rigs and production facilities.

Communities can be defined based on species composition as well. Generally speaking, two such seaweed algal communities are found in the study area:

- an open Atlantic association of the north and east coasts that occurs in deeper cold water, mainly below 25 m; and
- a community associated with the more protected waters of the south and west coasts that includes species at the northern or southern limits of their ranges.

Within these two communities are species that exhibit winter-spring growth, and those that exhibit summer-autumn growth. Three reproductive periods have been identified: winter (December to April), spring (March to July) and summer-autumn (June to November). The reproductive gametes are planktonic, thus allowing ready dispersal to other areas of suitable conditions. Thus, drilling rigs that provide suitable hard substrates at suitable depths and light conditions are readily colonized. Macrophytic algal communities exhibit zonation patterns, with different species growing at different depths or at different elevations of the intertidal zone. This zonation is evident on the artificial substrates of the drilling rigs as well.

Marine vascular plants, primarily eelgrass and cord grass of salt-marshes, are found only on fine-grained soft bottoms in shallow protected embayments. They are not present at White Rose.

Microalgae and coralline algae are important components of the benthos in water depths shallower than 30 to 50 m. Macrophytes (seaweed) are important at water depths shallower than 30 m.

Extensive macrophyte beds are unlikely in the White Rose area, where water depths are too great to allow proper light conditions for development. However, opportunistic macrophyte communities will develop on drilling or production structures located in this area.

3.4.2 Benthic Fauna

Benthic animals live in, on or attached to the sea bottom. Infaunal animals live within the sediment and can include bivalves (clams), polychaete worms, some crustaceans such as amphipods and cumaceans and other kinds of animals. Filter feeding infaunal animals feed directly on plankton, while detritovores feed on the bacteria associated with detritus. Detritovores may feed on the sediment surface or ingest sediment and extract whatever nutritive value it contains. In offshore waters, the source of this detritus is phytoplankton that sinks to the bottom, zooplankton faecal pellets and other organic matter of pelagic origin. In nearshore waters, marine algae and detritus in terrestrial runoff can also contribute to the detritus pool. Some benthic animals are carnivores and feed on other benthic animals. Hyperbenthic animals live in or on the substrate but are also active swimmers in the layer above the bottom. Epibenthic animals live attached to hard substrates.

Benthic community structure, animal and plant distributions and standing crop of benthic animals are related to water mass characteristics, primarily temperature, water depth, food supply, predation within the benthos, predation by fish and other pelagic predators, disturbance and the passage of time.

Benthic communities are not static entities. They change in response to disturbance by fishing gear, predation and the passage of time. A community that has sustained heavy predation or disturbance from fishing gear may be very different from the pre-disturbed community and the communities that represent stages in succession from the disturbed state to a climax state. Because of predation, disturbance, differences in microhabitat over short distances and the dynamics of benthic communities, abundances of benthic animals are highly variable, even within small areas (Vezina 1988; Downing 1989; Schneider et al. 1987; Schneider and Haedrich 1991). Because of the high variance, differences among locations or over time can only be demonstrated if there are large differences in animal abundances and/or species composition.

Historically, benthic studies included the following (in order of increasing detail):

1. taxonomic descriptions of the kinds of animals present;
2. descriptions of the kinds of communities present;
3. investigations of the relationships between animals and communities and the physical attributes of their environment;
4. reproductive studies that include long-term population dynamics;
5. investigations of the relationships between standing crop, community structure and food supply; and
6. trophic dynamic studies of the relationships between and among benthic animals including studies of the effects of predation and disturbance.

Historically, predation by fish on the Grand Banks benthos was intense, as was disruption by fishing gear. Studies of benthic communities or even individual species on the Grand Banks have not been conducted beyond the third level described above. Thus, data are insufficient to explain the observed distribution of animals and to relate apparently different communities to the stages of succession within communities. Grand Banks benthic communities that have been classified as "different" may represent different stages of succession of the same community and there may be fewer basic community types than described by Nesis (1965) and Hutcheson et al. (1981). Overall effects of fish predation and recent changes in fish abundance and fishing effort on Grand Banks benthos have not been studied. The causes of the decline in fish stocks may have also caused changes in benthic community structure apart from changes related to predation and disturbance from fishing gear. Long term cycles in benthos and plankton related to cyclical changes in hydrography have been noted in other parts of the North Atlantic (Gray and Christie 1983).

As indicated in Petro-Canada (1996), there was a collaborative research project on the effects of trawling on the Grand Banks conducted by the Bedford Institute of Oceanography (BIO) and the Northwest Atlantic Fisheries Centre (DFO, St. John's), between 1993 and 1995. The research was conducted in an area about 50 km northwest of White Rose that has been closed to trawling since 1987 (centre position at 47°10'N, 48°17'W). The depth range at the trawling impact study site was 120 to 146 m, similar to the water depth at White Rose. The project involved assessing the effects of one type of bottom trawl on a relatively homogeneous, sandy environment. Extensive video-guided sediment, infaunal and epibenthic sampling was conducted. Results are contained in Gordon et al. (1998) and Prena et al. (1999). Refer to the 'Trawling Impact Study' Section 3.4.2.3.

Site-specific studies of the benthos at the White Rose drill sites have been conducted by JWEL by reviewing seabed videotapes supplied by Dominion Diving and Fugro-Jacques Geosurveys, a seabed survey report by McElhanney, and core photos and field notes from Hibernia and Terra Nova. The videotapes covered a 50 m radius around the White Rose wells where depths ranged from 120 to 125 m. The conclusions of this review are summarized below (C. Hollett, pers. comm.).

The bottom substrate and topography at White Rose are generally typical of the northeastern region of the Grand banks, including Hibernia and Terra Nova. However, substrate at White Rose appears more similar to Hibernia, with surficial sediments approximately 90 percent fine to medium sands, with low relief patches of coarser sand and some gravel, whereas Terra Nova has more exposed gravel/cobble. The seabed is flat, fairly hard, with a gentle slope to the northeast.

According to the videotapes, American plaice, sand lance, snow crab, brittle stars and sand dollars are common at White Rose in the immediate vicinity (that is, within a 50 m radius) of the well sites.

Husky Oil conducted a baseline characterization program in the summer of 2000, consisting of a biological cruise in July and a sediment (benthic) cruise in September. The following briefly summarizes the preliminary information (based on photographs and the filed data sheets) available from the cruises.

The primary purpose of the biological cruise was to collect American plaice and snow crab samples to conduct body burden analyses and multi-function oxygenase/histopathology/haemotology (in American plaice only). Snow crab were selected due to the abundance indicated on the video tapes [see above]. American plaice were selected as the species common to all three sites (White Rose, Terra Nova and Hibernia) to allow for possible future common EEM programs; American plaice were also found to be numerous in the White Rose Area. All the crab and American plaice samples were collected (using a Campellan trawl) in four tows (transects) in the White Rose area (Figure 3.4-1). In addition to the crab and American plaice, all by-catch were identified and enumerated (Table 3.4-1).

The primary purpose of the sediment cruise was to collect sediment samples for chemistry and toxicity analyses and identification of benthic infaunal invertebrates. Any epibenthic species on the surface of each core was identified (Table 3.4-2). As the list in Table 3.4-2 indicates, the species composition and substrate type are farily consistent at all stations (which range from around glory holes to up to 18,000 m from the FPSO).

Samples were collected from the sea bottom using a box corer, which took a minimum of three cores (usually 10 to 20 cm collected per core) at each station. Approximately 30 percent of the sediment samples (cores) had black patches/spots, suggesting anaerobic or anoxic conditions.

The core samples were all sand, supporting the conclusion that the sediment is very similar to Hibernia (as was determined from the video tape review [see above]).

The results identified during cruises were consistent with, and provide additional validity for, data used in the EIS (Part One).

Water samples were also taken for chemical analyses at 25 percent of the sediment sample stations and conductivity-temperature at depth (CTD) casts were taken at 50 percent of the sediment sample stations (water samples were also taken at the four biological cruise sites at 10 and 15 m depths and analyzed for trace metals and chlorophyll content).

Figure 3.4–1 Biological Cruise Transects

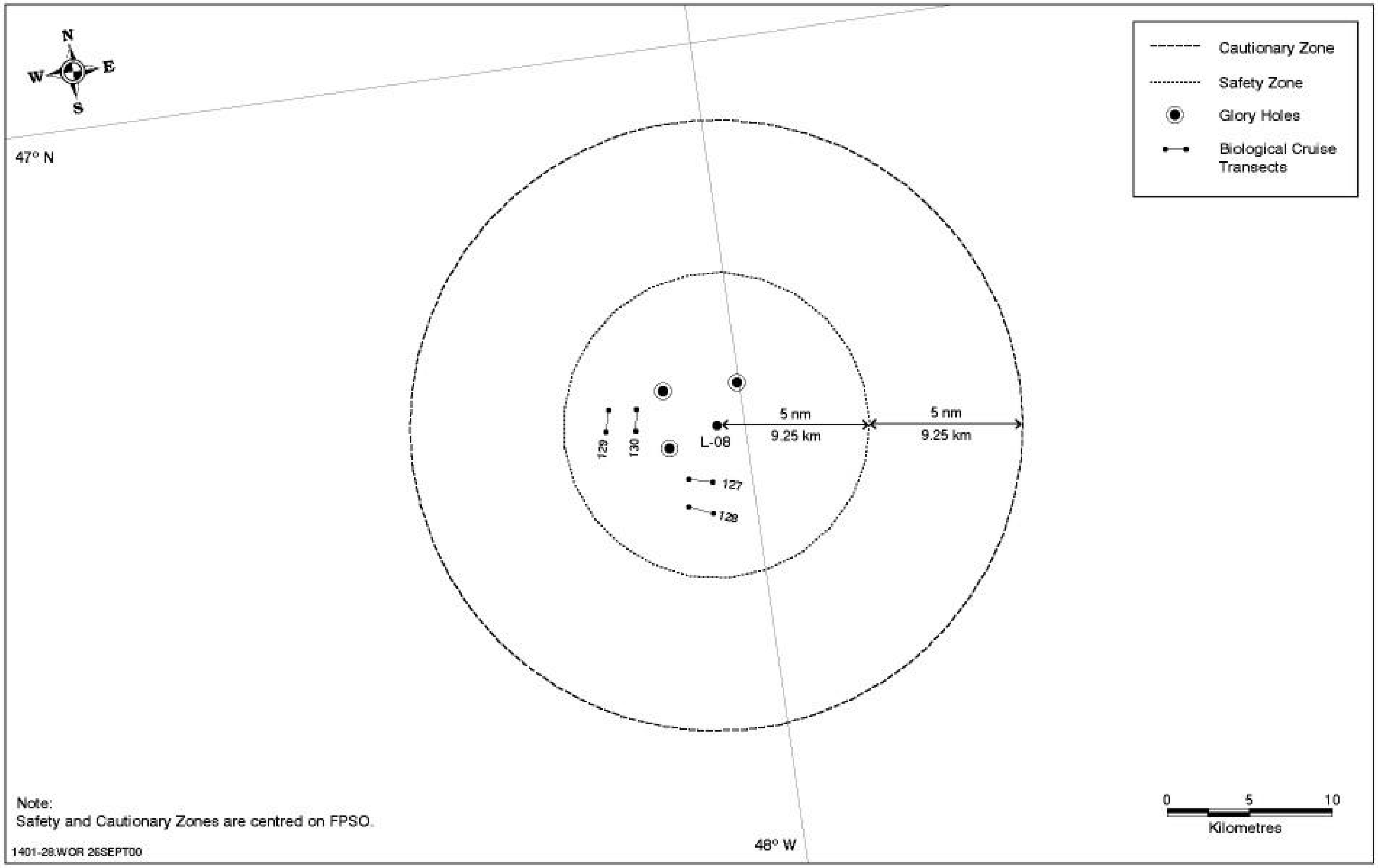


Table 3.4–1 Species Caught During White Rose Biological Cruise, July 2000

Species	Number Caught per Station			
	Station 1 (WR1)	Station 2 (WR2)	Station 3 (WR3)	Station 4 (WR4)
Thorny Skate	1		1	
Capelin	115	299	1,722	3,575
Arctic Cod		1	2	10
Sand Lance	29	11	226	230
Snake Blenny	7	1		
Arctic Eelpout	2	9		
Hookear Sculpin	6	9	6	10
Mailed Sculpin	166	221	67	90
Spatulate Sculpin			2	
Northern Alligatorfish	14	8	5	
Arctic Alligatorfish	15	26	7	
Common Alligatorfish		10		
Spiny Lumpsucker	3	1	1	
Seasnails	3			
American Plaice	13	18	6	8
Iceland Scallop		1		
Snow Crab	14	11	5	10
Toad Crab	1	1		
Invertebrates	Brittlestar, Sea Urchin, Sand Dollar, Sea Star, Sponge Total weight = 2.50 g (incl. shell fragments)	Brittlestar, Sea Urchin, Sand Dollar Total Weight = 2.39 g	Brittlestar, Sea Urchin, Sand Dollar, Jellyfish, Shrimp Total Weight = 5.36 g (incl. shell fragments)	

Table 3.4–2 Epifauna on Core Surfaces from Baseline Sediment Survey, July 2000

Sample #	Substrate	Epibenthos on Substrate*	Sample #	Substrate	Epibenthos on Substrate*
1	sand	sand lance, sand dollar, clams, scallop shell, sea urchin, brittlestar, tube worm, an unidentified irridescent polychaete	24	sand (a few pebbles)	brittlestars, sand dollars, clam, shell fragments, tube worms
2	sand	sand lance, sand dollar, brittlestar, clams, polychaete, scallop shell	25	sand	sand dollar, clam shell, tube worms, shell fragments, clam
3	sand	and lance, clams, sand dollar, brittlestar	26	sand (black spots throughout)	clam shells, sand dollars, polychaete, macoma, amphipod, shell fragments
4	sand	brittlestar, sand dollar, clams, polychaete, periwinkle	27	sand (black spots on sediment) (a few pebbles)	sand dollar, macoma, sand lance, polychaete, shell fragments
5	sand (several small cobbles)	brittlestar, sand dollar, clams, cockle, sand lance, tube worms, amphipod, barnacles on clam shell	28	sand (a few pebbles)	whelk, sea urchin, sand lance, sand dollar, brittlestar, clams, polychaete, shell fragments, amphipods, nematodes
6	Sand (a few small cobbles)	brittlestar, sand dollar, tube worms, clams, sea urchin	29	sand (a few pebbles)	brittlestar, shell fragments, nematodes, sand dollars, annelid, macoma, sand lance, sea urchin
7	sand (one large cobble with barnacles and tubeworms)	sand lance, brittlestar, sand dollar, tube worms, cockles, polychaete	30	sand	sand dollar, nematodes, shell fragments, sand lance, macoma, amphipods, clam shells
8	sand (some large gravel)	sand lance, sand dollar, brittlestar, tube worms, clams	31	sand (a few pebbles)	polychaetes, sand dollars, sand lance, clam shells, cockle, nematodes, sponges on pebbles, shell fragments, tube worms, macoma
9	sand	brittlestar, sand dollar, tube worm, clams, sea urchin, cockles, sand lance, amphipod	32	sand (a few small cobbles)	shell fragments, annelids, cockles, sand dollars, polychaetes, tube worms, nematodes, clams, whelks, sea urchins, sand lance, brittlestar
10	sand	sand lance, sand dollar, clams, tube worms, sea peach, cockle, brittlestar	33	sand	brittlestar, shell fragments, sand lance, small clam shells, periwinkle
11	sand	brittlestar, sea urchin, sand lance, polychaetes, sand dollar, nematodes, clams	34	sand (a few large gravel)	sand lance, brittlestar, sand dollar, shell fragments, sea urchin
12	sand	brittlestars, sand dollars, nematodes, polychaetes, whelk, sand lance	35	sand	brittlestar, sea urchin, small clams, sand lance, tube worms, sand dollar, shell fragments, clam shell
13)	sand	sand lance, sand dollar, nematodes, clam (shells), polychaete	36	sand (black sections in sediment) (one	brittlestars, shell fragments, sand lance, tube worms, small clam, red anemone attached to a small cobble

Sample #	Substrate	Epibenthos on Substrate*	Sample #	Substrate	Epibenthos on Substrate*
				small cobble)	
14	sand (black patches of sediment)	polychaetes, clam shells, brittlestar, sand lance, nematodes, shell fragments, sea urchin, macoma	37	sand (dark streaks in sediment) (a few small cobbles)	barnacles on one small cobble, brittlestar, sand dollars, sand lance, tube worms, small clams
15	sand (black patches of sediment)	brittlestar, polychaete, clam shell, macoma, sand lance, sand dollar, nematodes, shell fragments	38	sand (one medium cobble)	sand lance, sand dollars, small clams, sea urchin, brittlestar
16	sand (black patches of sediment)	brittlestar, sand dollar, sand lance, polychaete, nematode	39	sand	shell fragments, clam shell, sand lance, polychaetes, macoma, nematodes
17	sand (black spots on sediment)	polychaete, nematode, amphipod, shell fragments, clam, britllestar, macoma	40	sand	macoma, sand lance, nematodes, sand dollars, annelids
18	Sand (black patches of sediment, sulphuric smell)	annelids, polychaetes, shell fragments, brittlestar, sand dollar, macoma	41	sand (black patches, smell of anoxic sediment) (a few pebbles)	brittlestar, annelid, sand dollars, sand lance, nematodes, polychaetes
19	sand (black spots on sediment)	polychaetes, shell fragments, brittlestar, clam, tube worm	42	sand	brittlestars, sand lance, clam shells, sand dollars, macoma
20	sand (several small cobbles)	brittlestar, sand dollar, clam shells	43	sand (one small cobble)	sand lance, shell fragments, brittlestars, sand dollars, sea urchin, tube worms
21	sand	sand dollar, tube worms, lots of shell fragments, sand lance, scallop shell	44	sand	sand lance, sand dollars, shell fragments, macoma
22	sand (numerous large pebbles, several small cobbles)	brittlestars, sand dollar, clam, shell fragments, periwinkle, sand lance, tube worm, live Iceland scallop	45	sand (black spots on sediment) (a few small cobbles)	brittlestars, sand dollar, sand lance, cockle, tube worms, clam, polychaete, small bivalves
23	sand (a few small cobbles)	sand dollar, shell fragments, sand lance, small scallop shell, brittlestar, tube worms	46	sand (black patches throughout)	sand dollars, sand lance, nematodes, macoma, cockles, tube worms, brittlestars

* A minimum of three cores were taken at each sample location (six cores at each quality assurance/quality control station)

3.4.2.1 Standing Crop and Productivity

Infaunal benthos appears to decrease with increasing depth and is estimated to be approximately 168 g/m^2 at depths found at White Rose (Table 3.4-3). The average standing crop of infaunal benthic animals on the Grand Banks at depths between 51 to 421 m has been estimated at 481 g wet wt/m^2 (Hutcheson et al. 1981). The highest standing crops have been found in areas dominated by the bivalve *Mesodema*; Nesis (1965) recorded a biomass of 4.6 kg wet wt/m^2 in one of these areas. At one of Hutcheson's stations dominated by this bivalve, standing crop averaged 7.3 kg wet wt/m^2 (17 replicates over five sampling periods).

Table 3.4–3 Standing Crop of Infaunal Animals at Different Depths

Depth (m)	0-50	50-100	100-200	200-300	300-500	500-1,000	1,000-1,500
g/m^2	1,573	449	168	47	47	64	32

Source: Nesis 1965.

Hutcheson et al. (1981) estimated average annual infaunal productivity on the Grand Banks to be approximately 368 g wet wt/m^2 (128 kcal/m^2). The overall production to biomass ratio was 0.9 on a wet weight basis. These are relatively high standing crop and productivity estimates that reflect the high primary production on the Grand Banks.

3.4.2.2 Species Composition

At least 370 species of polychaete, echinoderm, crustacean and mollusc occur on the Grand Banks. Numerically, polychaetes are the most abundant infaunal taxa, and echinoderms and bivalves are dominant in terms of biomass (Hutcheson et al. 1981). Crustaceans are the dominant hyperbenthic animal. Deep water and northern areas of the banks contain Arctic/sub-Arctic assemblages. Temperate species are characteristic of shallow water and southerly portions of the banks.

Filter feeding and surface deposit feeding are the most common modes of feeding used by the Grand Banks benthos (Hutcheson et al. 1981). Hutcheson et al. (1981) suggest that this reflects a direct linkage between plankton production and benthic communities.

The Hibernia EIS identified 12 benthic communities on the Grand Banks based on the combined work of Nesis (1965) and Hutcheson et al. (1981). Each community was associated with specific substrate, depth, geographic location and water mass characteristics.

Hutcheson et al. (1981) found no evidence of major seasonal changes in the structure of benthic communities during a period of less than one year. They did find seasonal changes in the abundance of some individual species.

3.4.2.3 Trawling Impact Study

Exploratory sampling in 1992 at the trawling effects study site demonstrated that the benthic community was species rich (at least 139 macrofaunal species with an average of over 2,000 individuals/m^2), had a high number of epibenthic species, was high in biomass (mean of six grabs was 650 g wet wt/m^2) and had a relatively homogeneous species composition (Prena et al. 1999). Secondary hard-bottom structures such as mussel reefs were not present and sessile epifaunal species (for example, the soft coral *Gersemia* spp. and the bryozoan *Myriaspora* spp.) occurred in low densities. Schneider et al. (1987) described the patchiness of epibenthic fauna in this region of the Grand Banks.

An epibenthic sled was used to sample epifauna and some infauna (2 to 3 cm deep) at the affected site. Each sample represented approximately 17 m^2 of substrate. The total biomass of organisms collected by the sled ranged between 317 and 475 g wet wt/m^2. Nine dominant species were present in more than 90 percent of the samples and made up at least 95 percent of the mean biomass (Prena et al. 1999) (Table 3.4-4).

Table 3.4–4 Nine Dominant Species and Their Respective Mean Biomass Ranges (Epibenthic Sled Samples)

Species	1993 (g/m^2)	1994 (g/m^2)	1995 (g/m^2)
Echinarachnius parma (sand dollar)	168-296	162-243	180-321
Ophiura sarsi (brittle star)	46-75	36-76	40-88
Strongylocentrotus pallidus (sea urchin)	21-41	13-42	23-35
Astarte borealis (mollusc)	< 10	< 11	< 11
Chionoecetes opilio (snow crab)	< 9	< 6	< 14
Gersemia spp. (soft coral)	< 3	< 4	< 3
Margarites sordidus (mollusc)	< 2	< 1	< 1
Clinocardium ciliatum (mollusc)	< 2	< 1	< 2
Cyclocardia novangliae (mollusc)	< 1	< 2	< 1
Total sample (all species)	305-433	291-352	261-475

Source: Prena et al. 1999.

The three dominant species in sled samples were echinoderms. The polychaete *Nothria conchylega* was also abundant in all sled samples, but it was not processed because of the extensive sorting time required. The total number of species collected by sled sampling was 115 (Prena et al. 1999).

The trawl invertebrate bycatch was dominated by snow crabs (*Chionoecetes opilio*), basket stars (*Gorgonocephalus arcticus*) and sea urchins (*Strongylocentrotus pallidus*). Adult and immediately pre-adult male snow crabs comprised more than 70 percent of the crab bycatch biomass. Soft corals (*Gersemia* spp.), whelks (*Buccinum* spp.) and hermit crabs (*Pagarus* spp.) were common in the small amount of remaining bycatch. The overall mean trawl bycatch biomass was on the order of 10 kg wet wt) per set (approximately 260,000 m^2). The highest set mean biomass was approximately 19 kg/set. The patchiness of the epibenthic fauna was reflected by trawl results (Prena et al. 1999).

Only snow crabs and sea urchins were commonly caught by both the otter trawl and sled. Based on above numbers, the catch biomass per unit area using the sled was 10,000 times that of the trawl (Prena et al. 1999).

Schwinghamer et al. (1998) reported that video surveys conducted during the same trawling effects study readily observed high concentrations of sea urchins, snow crabs, sand dollars, basket stars and brittle stars throughout the trawl study area.

Gordon et al. (1998) reported that there were at least 238 macrofaunal species sampled during the Grand Banks otter trawling experiment, faunal biomass was approximately 1 kg/m^2 and that the benthic community was relatively homogeneous. The extensive database of epibenthic and infaunal invertebrates collected with the video grab (200 samples) is currently being analyzed (Gordon et al. 1998).

3.4.2.4 Interactions with Fish

The feeding habits of 14 of the most common fish species on the Grand Banks are shown in Table 3.4-5. Infaunal and hyperbenthic animals comprise a substantial proportion of the diet of these common fish species. Decapods and echinoderms are especially important in the diet of these fish. Polychaetes and crustaceans are important food items for young cod (Paz et al. 1993).

3.4.2.5 Interactions with Fishing

In 1985, approximately 236,100 h were spent trawling on and near the Grand Banks (Messieh et al. 1991). This represents approximately 1,300,000 km of trawling effort. The total area swept by bottom fishing gear could be approximately 9,000 km^2 (estimated from data in Messieh et al. 1991). Effects of bottom fishing can include direct mortality of individuals, indirect mortality through exposure of animals to increased predation by fish attracted to the area and long-term changes in benthic community structure (Messieh et al. 1991).

Table 3.4–5 Stomach Contents of Common Fish Species as Percentage Volume

	Atlantic Wolffish	Spotted Wolffish	Atlantic Cod	Longfin Hake	Common Grenadier	Roughhead Grenadier	Witch Flounder
Gammarid amphipods			0.1		3.5	0.2	6.7
Cumacea					0.2		0.5
Decapods	3.7	28.6	9.1	53.7	24.5	29.6	
Isopods							0.1
Echinoderms	28.8	30.3	1.3		1.0	5.4	5.7
Molluscs	2.2	0.3			1.7	1.9	4.6
Anthozoa	1.0	0.2				0.3	
Polychaetes	0.5	0.3	0.4		22.3	4.8	80.1
Sponges		2.0					
Tunicates						0.1	
Sipunculids							1.8
Total fish and pelagics (%)	63.8	38.3	89.1	46.3	46.8	57.7	0.5
Total benthic animals (%)	36.2	61.7	10.9	53.7	53.2	42.3	99.5
	American Plaice	**Greenland Halibut**	**Arctic Eelpout**	**Thorny Skate**	**Acadian Redfish**	**Golden Redfish**	**Deepwater Redfish**
Gammarid amphipods				1.2			
Cumacea							
Decapods	1.2	13.2	33.4	35.7	11.0	3.7	35.4
Isopods							
Echinoderms	86.3	0.2	52.8	0.1			
Molluscs	0.4	1.7	0.8	4.2			4.1
Anthozoa							
Polychaetes	0.8	0.1	3.4	2.2			0.2
Sponges							
Tunicates							
Sipunculids			0.2				
Total fish and pelagics (%)	11.3	84.8	9.4	56.6	89.0	96.3	60.3
Total benthic animals (%)	88.7	15.2	90.6	43.4	11.0	3.7	39.7

The trawling effects study conducted by BIO and the Northwest Atlantic Fisheries Centre between 1993 and 1995 also identified various interactions between fishing gear and the biological and physical aspects of the benthic environment (Prena et al. 1996; Schwinghamer et al. 1996; Rowell et al. 1997; Gilkinson et al. 1998; Gordon et al. 1998; Schwinghamer et al. 1998).

3.4.2.6 Intertidal and Nearshore Benthic Communities

Coastlines adjacent to the Grand Banks are rocky cliffs, fjord-like inlets and pebble cobble beaches. Some sand beaches and salt marshes are also present. Substrate, wave exposure and ice conditions are important determinants of the abundance and distribution of intertidal animals along the shoreline (Steele 1983). Inter- and intra-species competition for space and predation are also very important, and these species too are affected by ice scour and wave exposure.

The intertidal biota of Newfoundland is typical of that of the northwestern Atlantic. Barnacles, limpets, mussels, amphipods, and the predatory gastropod, *Thais* spp. are commonly encountered in the intertidal. Most intertidal and subtidal animals feed directly on plant material through grazing or suspension feeding. Gastropods, limpets and chitons are the dominant grazers in the intertidal zone. The sea urchin is probably the dominant grazer in rocky sublittoral environments. At depths below that occupied by urchins, chitons are the dominant grazer.

3.4.2.7 Biofouling

Biofouling refers to benthic organisms that colonize manmade structures. Fouling organisms increase friction between the surface and the water and affect manoeuvrability, wave loading and weight of offshore structures or platforms (Evans 1981; Hardy 1981). Fouling organisms, by their presence or through release of chemicals, can also cause or increase corrosion. A dense cover of fouling organisms can also interfere with inspections. Protection and cleaning of structures can be both dangerous and expensive as well as affect the environment. Thus, biofouling can be an operational, safety and environmental concern.

The fouling potential of the Hibernia site has been assessed in the review by Welaptega (1993). This report was limited by the lack of site-specific information, but made the following points that are also relevant to the White Rose Project.

- Microfouling, by bacteria, diatoms, protozoans, etc., if not properly controlled, can create operational problems such as blockage, dangerous hydrogen sulphide production and corrosion of steel structures. In addition, microfouling prepares the surface for macrofouling.

- Macrofouling can cause operational problems such as blockage and excessive loadings. Major organisms include macrophytes, soft invertebrates (hydroids, sea squirts, etc.) and hard invertebrates (mussels, barnacles, etc.).

Welaptega (1993) also modelled the amount of potential buildup based upon information from other areas. The riser, the floating platform and other subsea structures will likely be subject to colonization by fouling organisms. Offshore structures act as artificial reefs and are colonized by a wide variety of plants and animals (Forteath et al. 1982). Colonizing organisms can include attached forms such as seaweeds, hydroids, byozoans, barnacles, sea anemones, sea cucumbers, tunicates, tube dwelling polychaetes and mussels (Forteath et al. 1982). Mobile grazers and predators such as starfish, urchins, limpets, gastropods, amphipods and chitons can also colonize structures (Forteath et al. 1982).

Availability of spat (larvae), competition for space and illumination would be the dominant factors shaping the species composition of a fouling community on the Grand Banks.

Sessile animals produce pelagic larvae with a fixed life span. If the larvae do not find suitable substrate within a fixed time period, they die. Current patterns are an important determinant of the kinds of animals found on offshore structures; if currents carry live spat from breeding coastal populations to offshore structures, then intertidal biota will have an opportunity to colonize them.

The north shore of Newfoundland is the most likely source for intertidal animal larvae that could settle on structures at White Rose. The inshore branch of the Labrador Current passes along the north shore of Newfoundland, then divides into a southward-flowing current and an eastward-flowing current. The eastward-flowing branch flows along the northern Grand Banks to its northeast corner, where it joins the offshore branch of the Labrador Current, which then flows south. The core of this southward flowing current passes very close to the White Rose site. The current itself, eddies or wind events could bring larvae onto the White Rose site.

Because of ice scour, attached intertidal life is sparse along exposed areas on the north coast of Newfoundland (South 1983). In sheltered areas, intertidal life is comparable to that found in other parts of the Island. Barnacles, mussels, *Chondrus* spp., and the rockweed *Fucus* spp. are common in intertidal habitats (South 1983; Steele 1983). The pattern of zonation in the subtidal zone is determined by grazing of the sea urchin *Strongylocentrotus droebachiensis* (Steele 1983). In the absence of grazing, competition for space would determine zonation on production facilities. The kelps, *Laminaria* spp., *Agarum* spp. and *Alaria* spp., the red algae, *Ptilota* spp., encrusting red coralline algae and *Desmarestia* spp. are common subtidal plants (Steele 1983). These could all be considered as potential fouling organisms.

Desmarestia spp. is a particularly noxious fouling plant because when damaged, as through wave action, it releases free sulphuric acid, which can accelerate corrosion (Hardy 1981). The filamentous algae, *Enteromorpha* spp., can withstand wide fluctuations in environmental conditions and so is considered a cosmopolitan fouling plant (Evans 1981). *Enteromorpha* is found on the north shore of Newfoundland (South 1983).

In the North Sea, kelps have colonized platforms a hundred or more miles from shore (Moss et al. 1981). Zoospores can live for up to 80 days; millions are released by each plant. Young plants can be free floating and then attach themselves to solid structures.

Viable fertile barnacles, mussels, kelp and filamentous algae on supply boats and oil-transfer ships could also be a source of fouling organisms.

Starfish are not usually able to reach shallow regions of platforms that are anchored to the bottom (Forteath et al. 1983). Starfish and other predators and urchins may be unable to reach a floating production platform or the top parts of the riser pipe and so predation may be minimal. A lack of grazing by urchins could allow extensive fouling by large macrophytes.

In time, a clear pattern of zonation related to water depth and illumination would be evident on offshore structures. There would also be changes in species composition over time. Early colonizers may not be able to compete for space with other animals and would subsequently diminish in importance or be excluded altogether. Growth of fouling organisms may be quite rapid. Animals that normally inhabit the intertidal zone are always immersed in water when attached to offshore structures and so can feed continuously (Forteath et al. 1983).

Animals that normally live in the intertidal zone may not have restricted depth distribution in offshore waters. In the North Sea, the barnacle *Balanus crenatus* can be found between near mean low water (MLW) and 60-m depth, and the mussel *Mytilus edulis* can dominate the fouling community from MLW to depths of 30 m on oil and gas platforms (Forteath et al. 1983).

3.5 OTHER MICROBIOTA

Other members of marine plankton and benthos include microscopic organisms such as viruses, bacteria, yeasts and fungi that are not primary producers. Relatively little is known about marine viruses, yeasts and fungi in the northwestern Atlantic. Yeasts and fungi are generally more common in estuarine and coastal environments than in the open ocean. They degrade organic matter, including petroleum hydrocarbons, but their role in the marine ecosystem may be relatively unimportant.

Much more research has been done on marine bacteria, and they play an important role in the marine ecosystem. Most marine bacteria consume organic substances for carbon and energy, and occur in both the water column and in benthic sediments. They convert dissolved organic carbon (DOC) from phytoplankton into particulate bacterial biomass that is then available to higher levels of the food chain. Estimates of the portion of primary production that passes through bacteria range from 10 to 50 percent (Mobil 1985). Some marine bacteria "oleoclasts" are able to degrade petroleum products. Oleoclastic bacteria are found as natural components of virtually all marine aquatic communities, although their activity may be low in pristine non oil-polluted areas.

Bédard and Bunch (1983) found that the activity of heterotrophic bacteria was highly correlated with the biomass and activity of phytoplankton, although other factors modified the relationship. These bacteria were responsible for maintaining DOC levels at fairly constant levels, and increased in activity when DOC input presumably increased during the spring phytoplankton bloom. Their abundance and activity on the Grand Banks has been found to be comparable to those of other marine areas with similar food chains (Bédard and

Bunch 1983). The bottom sediments have far greater bacterial activity than the water column, and may contribute half the bacterial mineralization on the Grand Banks. Bacterial activity in the sediments exhibited little temporal variation, apparently unaffected by the supply of organic matter from the water column. Activity and abundance in the sediments was related to the organic carbon content of the sediments.

The potential activity and abundance of oleoclasts in both the water column and the sediments were judged to be low, particularly in July. Other evidence suggests that the natural populations of oleoclasts in the water column of the Grand Banks is an order of magnitude lower than most other uncontaminated marine environments (Mobil 1985). Bédard and Bunch (1983) speculated that interactions between temperature, nutrients and naturally occurring cycles of oleoclastic populations will determine the rate of biodegradation of any petroleum released on the Grand Banks. Lee and Levy (1989) note that microbes in the sea are able to increase and decrease their activity over a wider range than any other group of organisms, and that they remain dormant until conditions become favourable.

Considerable research on the role of bacteria in the spring bloom of North Atlantic waters has been conducted as part of the Cold Ocean Productivity Experiment (Pomeroy and Deibel 1986; Pomeroy et al. 1991) and the North Atlantic Bloom Experiment (Li et al. 1993). While the details of bacterial production have not been fully described, it is clear that their role in the bloom can be significant, depending on environmental conditions. Pomeroy et al. (1991) found that the numbers of free-living heterotrophic bacteria in Newfoundland coastal waters during the spring bloom were at the low end of the range for oceanic waters. They found growth rates varied considerably with depth. Bacterial numbers are normally high in eutrophic systems. But this was not the case for Conception Bay in April and May, where both chlorophyll and photosynthetic rates were high. Pomeroy et al. (1991) concluded that microbial metabolism and production in cold waters are limited by the ability of bacteria to transport and/or assimilate substrates at the low temperatures and low concentrations of substrate normally present.

3.6 ICHTHYOPLANKTON

The following discussion on icthyoplankton (fish eggs and larvae) is based primarily on the extensive surveys conducted in the early 1980s by Bonnyman (1981) in support of the Hibernia EIS (Mobil 1985). This material has been updated by later research on the Flemish Cap (Anderson 1984) and the Grand Banks (Frank et al. 1992; Helbig et al. 1992; Myers et al. 1993; deYoung and Davidson 1994; Anderson et al. 1995) and the most recent MPE surveys by DFO (Anderson and Dalley 1997; Dalley and Anderson 1997; Anderson et al. 1999; Dalley et al. 1999). [See also 'Nekton' (Section 3.7) for more discussion on juvenile fish.]

At least 45 species of fish have been identified as early life stages in the ichthyoplankton of the Grand Banks and inshore waters of Newfoundland. The most frequently reported of these have been Atlantic herring (*Clupea harengus harengus*), capelin, Atlantic cod, sandlance (*Ammodytes* spp.), redfish (*Sebastes* spp.), seasnail

(*Liparis atlanticus*), witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*) and yellowtail flounder (*Pleuronectes ferruginea*). With the exception of sandlance and seasnail, these are all, or have been in the past, commercially important species in the fishery on the Grand Banks or inshore Newfoundland. On the Flemish Cap, a number of additional species have been found, but usually in low numbers. Redfish have dominated the ichthyoplankton in the Flemish Cap area, at least in the early 1980s.

Bonnyman (1981) found that seven of the nine species listed for the Grand Bank above comprised 87 percent of the total number of fish larvae taken throughout the Mobil cruises in 1980-81 (Table 3.6-1).

Table 3.6–1 Dominant Fish Larvae on the Grand Bank, 1980-1981

Species	Mean No./1000 m^3	percent of Total
Sand lance	188	65
Capelin	21	9
Redfish	12	6
Witch flounder	8	3
Yellowtail flounder	6	2
American plaice	4	1
Atlantic cod	2	1

The most striking feature of the ichthyoplankton on the Grand Bank during 1980-81 was the complete dominance of sand lance (*Ammodytes americanus*). Its overall average abundance during 1980-81 was 188 fish/1,000 m^3, or nine times the abundance of capelin, the next most abundant species. The sand lance is a small, slender fish that is generally considered to be pelagic, but is often found buried in bottom sands and has benthic eggs. The sand lance is not important commercially, but other commercial fish feed on it extensively, and in coastal regions it is an important food item for seabirds.

The other six species are all of commercial importance. All but capelin are considered to be demersal (groundfish), although redfish may rise from the bottom, particularly at night.

Capelin are pelagic and, aside from their commercial importance, are a key item in Grand Banks food web, being a principal food item of whales, seals, seabirds and other fish. Capelin spawn inshore on gravel beaches, where the adhesive eggs take about two weeks (depending on temperature) to hatch. In addition to these inshore spawners, an offshore spawning population is located on the Southeast Shoal area.

Redfish eggs are retained within the body of the female and the young are "extruded" when fully developed. The remaining species -- cod, witch flounder, yellowtail flounder and American plaice -- all have pelagic eggs that float near the surface during incubation. Consequently, their distribution is affected by ocean currents.

3.6.1 Geographic and Seasonal Distribution

The following description is based on seven geographic subdivisions of the Grand Banks (Figure 3.6-1): the Inshore area; the Avalon Channel-St. Pierre Bank area; Central Grand Bank; North and East Slopes; the Southeast Shoal and Tail of the Bank; the Southwest Slope; and the deep water off the banks.

The seasonal distribution of the dominant ichthyoplankton species within these subareas of the Grand Banks for the years 1980-81 is illustrated in Figure 3.6-2. ['Mean numbers' in the following descriptions refer to the average for a number of samples collected in a particular subarea or over a specific time period. Maximal mean numbers refer to a specific subarea or time where average densities were highest.]

3.6.1.1 January

The ichthyoplankton community was sparse. However, newly hatched sand lance larvae (6 to 10 mm in length) could be found on the Southeast Shoal, as well as a few scattered juvenile capelin (hatched the previous year).

3.6.1.2 March

Sand lance larvae increased in number and were more widely distributed across the Grand Banks. American plaice and cod-type eggs (CHW eggs -- cod, haddock (*Melanogrammus aeglefinus*) or witch flounder) were present on the Grand Banks and on the slopes in low numbers.

3.6.1.3 April

Sand lance larvae were widely distributed on the Grand Banks and appeared to be at their maximum concentration in some areas; the mean concentration of sand lance in the Southeast Shoal and Tail area was 7,801 fish/1,000 m^3. In the deep waters off the slopes and along the slopes (but not on the Grand Banks), redfish larvae appeared in the ichthyoplankton. Of the egg component of the ichthyoplankton, plaice eggs were dominant in April, and were fairly widespread in inshore area and on the Grand Banks. CHW eggs were found in small numbers in all areas.

Figure 3.6–1 Geographic Subareas of the Grand Banks Relevant to Ichthyoplankton

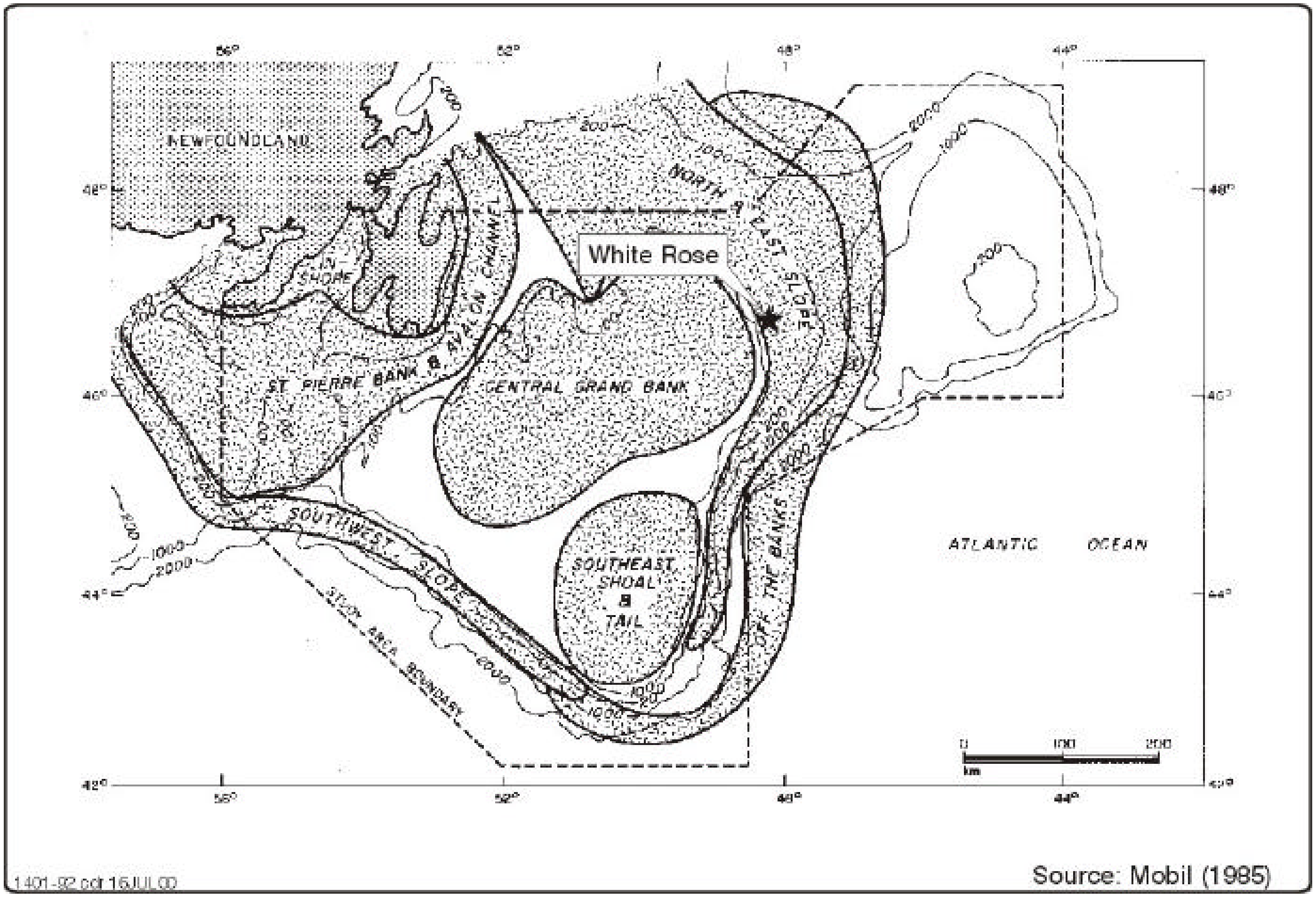
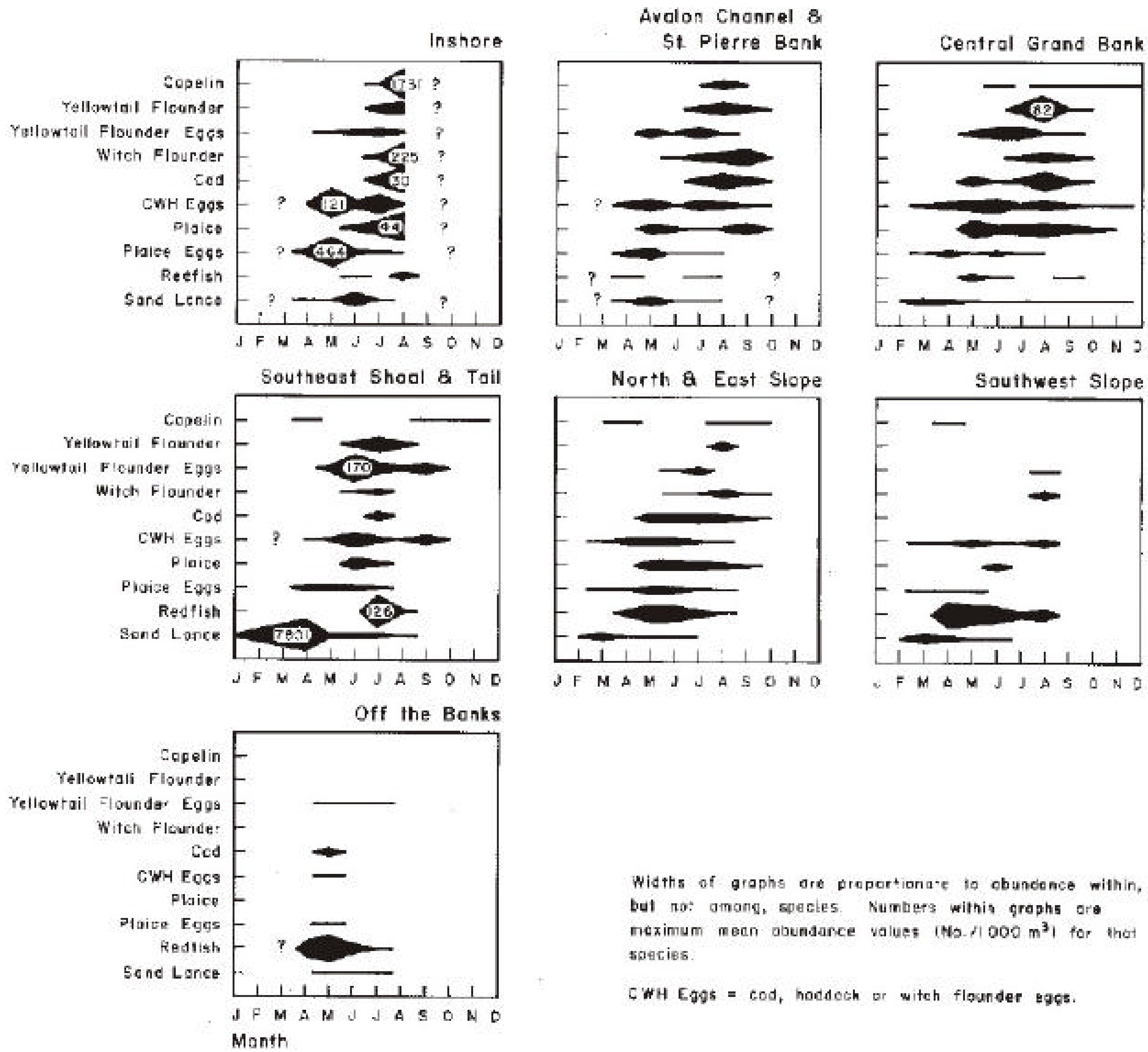


Figure 3.6–2 Seasonal Distribution of Dominant Ichthyoplankton Species on the Grand Banks: 1980-1981



Source: Mobil (1985)

3.6.1.4 May

Sand lance larvae were still widely distributed, and cod and plaice larvae appeared in small numbers on the Central Grand Bank and the Northeast Slope. Redfish were found in close to maximal mean numbers and were still largely confined to the shelf slope and deep waters off the shelf. Maximum mean numbers of both plaice (464/1,000 m^3) and CHW (121/1,000 m^3) eggs were found in May in the Inshore region. While plaice eggs were found over most of the Shelf, CHW eggs were largely confined to the north half of the Grand Banks. Yellowtail eggs were present in small numbers in all areas except the deep water off the shelf.

3.6.1.5 June

Yellowtail eggs reached a maximal mean of 170/1,000 m^3 on the Southeast Shoal and Tail area of the Grand Banks, and were abundant on the Central Grand Bank. CHW eggs were still relatively abundant, particularly in the Avalon Channel-St. Pierre Bank, the Central Grand Bank and the Southeast Shoal and Tail areas. The number of plaice eggs had declined, but moderate numbers were still found on the Central Grand Bank and the Southeast Shoal and Tail areas. In most areas, the number of sand lance larvae was declining in June, however, the mean number of sand lance larvae was high in the Inshore region (mean = 1,717/1,000 m^3), primarily because of high numbers in the mouths of Placentia and St. Mary's bays. These larvae averaged 25 to 31 mm in length, and so had not been newly hatched. Redfish larvae were still found along the shelf break and in deep water, while relatively small numbers of plaice were found everywhere but the deep water off the banks. Cod larvae were confined to the Central Grand Bank and the Northeast Slope areas. Witch flounder larvae made their first appearance of the year in June in the Avalon Channel-St. Pierre Bank, Southeast Shoal and Tail and Northeast Slope areas.

3.6.1.6 July

There was an increased dominance of flatfish eggs and larvae, and a decrease in other species, particularly sand lance. The number of plaice eggs continued to decline, while CHW eggs maintained relatively high concentrations, particularly in the Inshore, Avalon Channel-St Pierre Bank, Central Grand Bank and Southeast Shoal and Tail areas. In most areas, numbers of redfish larvae continued to decline, however, high numbers of newly extruded larvae were found at two stations close to the shelf break in the Southeast Shoal and Tail area, resulting in the highest mean concentration of redfish for this area (126/1,000 m^3). It appears that a second spawning of redfish occurs on the slope of the Grand Banks, as is thought to occur on the Flemish Cap. Cod larvae were found in small numbers in all areas except the deep water off the shelf and the Southwest Slope; American plaice larvae were similarly widely distributed. Yellowtail larvae were relatively abundant in the Inshore region, on the Central Grand Bank and in the Southeast Shoal and Tail region. Witch flounder were found in most regions (except the deep water off the shelf), but were most abundant in the Inshore and Avalon

Channel-St. Pierre Bank regions. Capelin larvae made an appearance for the first time of the year in the Inshore and Avalon Channel-St. Pierre regions.

3.6.1.7 August

The Inshore region appeared to be important for ichthyoplankton. Capelin larvae in maximal numbers dominated the plankton in this region (mean = 1,731/1,000 m^3), but American plaice (44/1,000 m^3), cod (30/1,000 m^3) and witch flounder (225/1,000 m^3) all exhibited their maximal mean numbers at this location and time. Yellowtail larvae were also abundant in the Inshore region, and reached maximal mean numbers of 82/1000 m^3 on the Central Grand Bank in August; capelin, American plaice, cod and witch flounder were abundant here as well. Sand lance and redfish larvae had declined in importance as components of the ichthyoplankton in August, as had plaice, CHW and yellowtail eggs.

3.6.1.8 September

Capelin, cod, witch flounder, plaice and yellowtail larvae were still important components of the ichthyoplankton in the Avalon Channel-St. Pierre Bank and Central Grand Bank areas. It is likely that they were important in the Inshore region as well, but no sampling occurred in this area in September. CHW and yellowtail eggs were still found in small numbers on the continental shelf, but not in the slope areas or off the shelf. Redfish and sand lance had almost completely disappeared from the plankton by this time.

3.6.1.9 November

The ichthyoplankton declined to winter low; only low numbers of capelin and occasional specimens of sand lance and plaice were found.

3.6.1.10 Seasonal Summary

The ichthyoplankton of the Grand Bank area can be described as having two peaks (Bonnyman 1981; Mobil 1985; Petro-Canada 1996). The first is an April-May peak which is dominated by sand lance on the continental shelf and redfish on the slopes and in the deep water off the slope. The second, which takes place primarily in waters close to shore (and in the Central Grand Bank and Southeast Shoal areas for yellowtail) in August is characterized by the emergence of capelin larvae associated with peak numbers of cod and flatfish larvae.

3.6.2 Vertical Distribution

Knowledge on the vertical distribution of fish eggs and larvae in the plankton is important for assessing the effects of oil spills. The 1980-81 data indicate that the overall concentration of fish eggs in the surface waters (as determined from Neuston surface samplers) was approximately 100 times greater than an average concentration through the water column to 70 m (as determined from oblique bongo tows). The concentrations of CHW (cod, haddock, or witch flounder), American plaice, and yellowtail flounder eggs all were considerably higher in the surface samples than in the depth-integrated samples. The depth distribution of larvae was less distinct. While plaice, cod, redfish and witch flounder larvae were all in lower concentrations in the surface samples than in the depth-integrated samples, the concentrations of capelin and sand lance larvae in surface and depth-integrated samples were not substantially different. Vertical distribution is discussed further in Section 3.6.3.2.

3.6.3 Post-1980s Ichthyoplankton Research

The work published since 1984 has mostly been done by researchers of DFO or Memorial University. This information tends to focus on particular species (Atlantic cod, capelin, yellowtail flounder, redfish) and/or on particular subareas of the Grand Banks (the Southeast Shoal; the shelf break; northeast Newfoundland bays). Little additional information has been reported on the ichthyoplankton of the northeast Grand Bank, in the vicinity of the White Rose oil field since Mobil (1985), although the 1994 to 1998 MPE surveys by DFO are of some relevance (see below).

Much of the recent work has focused on testing two hypotheses related to the importance of egg and larval survival success to recruitment (deYoung and Davidson 1994):

1. the match/mismatch hypothesis that larval survival is dependent on the timing of larval emergence in relation to the timing of peak numbers of zooplankton food items; and
2. that larval survival is dependent on the retention of larvae in zones favourable for their development.

Between 1994 and 1999, DFO has conducted large scale comprehensive surveys of the MPE off Newfoundland and Labrador. These late summer surveys (MPE surveys) were originally designed to measure the abundance of pre-recruit juvenile Atlantic cod and capelin and at the same time, temperature and plankton were also sampled (Anderson and Dalley 1997; Anderson et al. 1999; Dalley and Anderson 1997; 1998; Dalley et al. 1999). Limited ichthyoplankton information is available from the surveys conducted during 1994 to 1998, but data from the 1999 survey are not yet available (J. Anderson, pers. comm.).

3.6.3.1 Geographic and Seasonal Distribution

The retention of eggs and larvae in the general area where they are spawned is an important determinant of year-class strength (deYoung and Davidson 1994; Davidson and deYoung 1995), and cod, at least, spawn in areas where their eggs and larvae are likely to be retained (Hutchings et al. 1993). Helbig et al. (1992), using particle drift simulation modelling, concluded that Labrador shelf cod eggs and larvae are segregated from Grand Banks eggs and larvae. They also found that drift rates over the Grand Banks appeared to be slow enough to ensure that eggs and larvae are retained, and that special retention mechanisms, such as are thought to occur on the Southeast Shoal, are not necessary to ensure retention. Drift of eggs and larvae off the Grand Banks into water of unfavourable rearing conditions is not thought to be a critical problem (Myers and Drinkwater 1988).

deYoung and Davidson (1994) and Davidson and deYoung (1995), in modelling simulations of cod egg and larval drift, found that the northern Grand Banks was the most favourable spawning location from a "retention on the Grand Banks" perspective. This is consistent with the conclusion of Hutchings et al. (1993), who found that cod spawned all over the Grand Banks, but particularly on the northern half, and not exclusively on the shelf slopes as had previously been thought. It is also consistent with the findings of Bonnyman (1981) reported above, that cod eggs and larvae were often found in greatest concentrations on the north half of the Grand Banks.

It has been hypothesized that the bays of northeast Newfoundland are important juvenile nursery areas for the northern cod stock, after eggs and larvae drift from the northeast shelf into the bays. However, Helbig et al. (1992), using particle drift simulation modelling, concluded that storm tracks had to be extremely favourable to accomplish drift into these bays, and that the Newfoundland northeast shelf was a far more likely juvenile rearing area. This conclusion was supported by the work of Anderson et al. (1995), who found that cod eggs spawned offshore remained offshore, and that pelagic juveniles found in the inshore bays had probably been spawned inshore. These conclusions support those of Hutchings et al. (1993) who, in a review of information on cod spawning locations, concluded that local, inshore populations of cod may make a larger contribution to recruitment than was previously thought.

Frank et al. (1992) inferred spawning locations for three flatfish species from larval/juvenile distribution on the southern Grand Banks in 1986, 1987 and 1988, assuming passive advection in conjunction with measured currents in the area. For yellowtail, they inferred a spawning location of the Southeast Shoal in two of the three years. For plaice, they inferred a spawning location along the northern or northeastern Grand Banks, with southward drift in the Labrador current. There was little evidence that witch flounder had been spawned on the sides of the Grand Banks, as had been assumed in the past.

Capelin larvae, on the other hand, are rapidly dispersed to the Grand Banks after hatching on beaches in Newfoundland Bays. deYoung et al. (1994), using an advection-diffusion model, concluded that the residence time for capelin larvae that had been hatched at the head of Conception Bay was approximately 20 to 40 days. Larvae that were hatched on beaches closer to the mouth of the bay had a residency time as short as a few days.

It has been hypothesized that the development of ichthyoplankton is closely linked to an abundant food supply and a scarcity of predators; however, this is not always the case. Anderson and Gardner (1986), in an examination of the biological oceanography of the Southeast Shoal and shelf break, found high densities of sand lance and snail fish over the shallow area of the Southeast Shoal at a time when prey items (early stages of copepods) were in low supply and ctenophore predators were abundant. Frank et al. (1993), in a study of the spatial distribution of capelin larvae on the Southeast Shoal, concluded that older larvae have the ability to remain within patches of zooplankton prey. In contrast, Myers et al. (1993) noted that cod spawning in all areas always occurred prior to the peak of the main zooplankton food item for cod larvae. Myers et al. (1993) concluded that the timing of cod spawning is coupled to the timing of plankton production, but only in a general way, and that recruitment will not be strongly influenced by changes in the timing of the plankton peak.

During the 1994 and 1995 MPE surveys, few fish eggs were sampled on the Grand Banks during late summer, indicating very little spawning activity at that time (Anderson and Dalley 1997). Cunner/yellowtail flounder (CYT) eggs dominated during both years. Eggs of these two species are difficult to distinguish at an early stage and are therefore grouped as CYT. These eggs occurred primarily on the Southeast Shoal, which suggests they were yellowtail flounder eggs. The next most abundant eggs were CHW eggs, grouped for the same reason. Anderson and Dalley (1997) interpreted CHW eggs to be primarily witch flounder due to the absence of cod and haddock larvae in the samples.

During the 1994-95 surveys, capelin larvae were most abundant Inshore and least abundant on the Grand Banks, including the South Grand Bank, where they were fairly abundant in the 1980s. The absence of capelin larvae on the South Grand Bank in 1994 and 1995 might have indicated either the absence of spawning or late spawning. The low abundance of larval fish on the South Grand Bank in 1994 and 1995 was not expected considering the historical importance of the South Grand Bank as a spawning area for cod, capelin, American plaice and yellowtail flounder (Anderson and Dalley 1997).

As in 1994-95, capelin larvae showed a definite gradient of decreasing abundance with distance from shore in 1996, with areas of highest capelin larvae density occurring inshore in NAFO Statistical Division 3L. Herring larvae were also found in one distinct area in inshore Division 3L. Larval cod catches were lower in 1996 than in 1995 and 1994 (Dalley and Anderson 1997).

In 1997, the most abundant larval capelin catches were inshore, as was the case during the preceding three years. Low catch rates of larval cod occurred on the South Grand Bank and at one station on the Northern Grand Bank (Dalley and Anderson 1998).

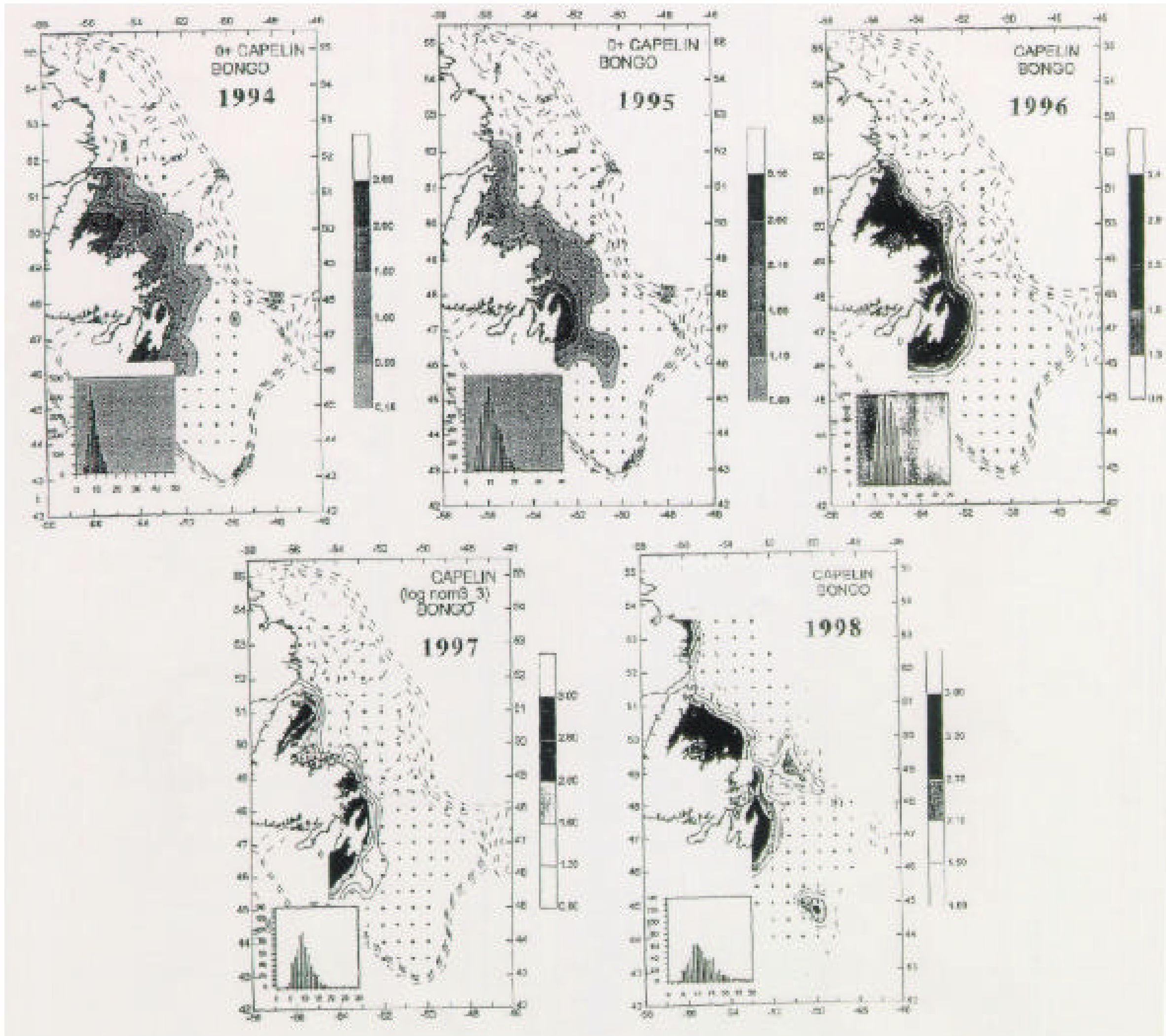
The distribution of capelin larvae during the 1998 MPE survey was similar to preceding years in that it was primarily coastal. For the first time in the five years of survey, larval capelin were found on the Southern Grand Bank at the Southeast Shoal. Also, in contrast to 1997, larval capelin distribution was dispersed further offshore, especially in the area of the Northern Grand Bank. Herring larvae were encountered inshore off the east coast of the Avalon Peninsula (Dalley et al. 1999).

During the 1994-1998 period, capelin larvae dominated the ichthyoplankton (50 to 90 percent of total numbers). No other fish species has occurred in substantial abundance as either eggs or larvae. Capelin have undergone an expansion of their range during the 1994 to 1998 period, the most dramatic increase being that observed for capelin larvae in 1998 (Figure 3.6-3). During 1994 to 1996, capelin larvae were observed only along the northeast coast of Newfoundland and within the Avalon Channel. In 1998, capelin larvae were observed at several stations along the coast of southern Labrador and on the Southern Grand Bank. Larvae sampled in the surveys were typically 10 to 20 mm in length, approximately 20 to 40 days old (Anderson et al. 1999).

The ichthyoplankton community of the Flemish Cap is strikingly different from that of the Grand Banks based on sampling between March and August. Here redfish (possibly three species -- *S. fasciatus*, *S. mentella* and *S. norvegica*), totally dominate the plankton community. Extrusion begins in March (Serebryakov 1978; Anderson and Akenhead 1980) and a first peak in abundance occurs in late April (Anderson 1981), at which time the larvae of this species makes up to 99 percent of all fish larvae (Grimm et al. 1980) in the plankton. Spawning appears to take place on the slope area around the bank; over time, the larvae are concentrated on the shallow bank, perhaps by the physical circulation patterns (Serebryakov 1978; Anderson 1981). In June, a second spawning of redfish occurs, with its abundance two or three orders of magnitude lower than the April-May spawning peak (Anderson 1982). This second spawning may extend into August. Even though total redfish mortality may exceed 95 percent between April and July (Anderson 1981), redfish remain the dominant ichthyoplankton species at this time.

Cod and American plaice eggs and larvae also occur on the Flemish Cap. Anderson (1982) estimated that peak hatching of cod larvae occurred in late April in 1981, and Serebryakov (1978) noted that American plaice eggs were present as early as late March, with a peak in numbers in the latter half of May. Other species occur in small numbers on the Flemish Cap, but unlike the Grand Banks, the pelagic species such as sand lance and capelin are never found in very large numbers.

Figure 3.6–3 Distributions of Larval Capelin Caught in the Bongo Samplers During Pelagic Environment Surveys, 1994-1998



1401-38.cdr 26JUN00 Figure3.6-3

Length Frequency Distributions Are Plotted In The Lower Left Corner Of Each Map.

Source: Dalley and Anderson (1997; 1998); Dalley et al. (1999)

3.6.3.2 Distribution in the Water Column

Frank et al. (1992) examined larval flatfish distribution on the Southern Grand Bank based on ichthyoplankton surveys in 1986, 1987 and 1988. Yellowtail larvae and juveniles reached peak concentrations between 18 and 28 m, at or near the thermocline, with only small numbers being found at the surface. Plaice larvae appear to occur mostly below the thermocline, and none were found in the surface 5 m. Witch flounder larvae were also centred around the thermocline (around 23 m), with only small numbers in the surface 5 m. All three flatfish species exhibit some daily vertical migration.

However, the vertical range of diel migration in yellowtail is small, as it is for plaice and witch, providing little support for the theory of retention via daily vertical migrations.

deYoung et al. (1994) found peak densities of capelin larvae within the top 40 m in Conception Bay, with smaller larvae being found at lesser depths than larger larvae. Frank et al. (1993), in an examination of larval capelin on the Southeast Shoal, found that all size classes exhibited diel vertical migration. The vertical range increased with larval size; for yolk-sac larvae, the range was about 15 m, whereas for large post yolk-sac larvae the range was > 40 m.

Anderson and deYoung (1994) found that the density of healthy cod eggs decreased with age and development, ensuring a positive buoyancy and that hatching would take place in conditions favourable for larval feeding and growth. Dead eggs sank rapidly and were lost to the bottom, and eggs increased in density when exposed to unfavourable water conditions such as low oxygen levels.

3.6.3.3 Interannual Variability

The concentration of fish eggs and larvae in the water column is subject to very large interannual variability (Frank et al. 1992). Myers and Cadigan (1993a; 1993b) concluded that variability in relative year class strength of groundfish is usually determined at the larval stage, but that this variability can be dampened by subsequent juvenile mortality. A variety of interacting factors contribute to the interannual variability in egg and larval populations, including parent stock size (for example, northern cod stock), the timing of spawning in relation to environmental factors such as capelin and onshore wind frequency, strength and direction of currents (flatfish on Southeast Shoal), freezing in cold, low salinity water (Divisions 2J3KL cod), spawning at the "right site" in relation to water temperature, spawning location and resulting retention time (cod in general), storm conditions and related degree of off-shelf transport, abundance of prey and predators, water temperature, salinity, and many other factors (Leggett et al. 1984; Myers and Drinkwater 1988; Walsh 1992; Myers et al. 1993; deYoung and Rose 1993).

3.6.3.4 Flemish Cap

Anderson (1984), in an examination of the early life history of redfish on the Flemish Cap, determined that redfish constituted at least 90 percent of all fish larvae sampled in 12 surveys during 1978 to 1982, all conducted between March and August. He confirmed that two peaks in larval extrusion occurred, one in early April (*S. mentella*), and a second smaller peak (*S. fasciatus*) in mid-June. In the early extrusion, larval abundances reached as high as 733 larvae/m^2. Anderson also noted that interannual variability could be high, and that larvae > 13 mm were an order of magnitude more abundant in 1982 than in 1981. The Mobil (1985) data indicated a similar pattern on the Southeast Slope, with two periods of peak extrusion, one in May and one in July. Anderson (1990) also examined the timing of the peak in copepod spawning in relation to the peak redfish extrusion period, and hypothesized that while the time of spring calanoid spawning did not vary much (mid to late April), the interannual variations in the rate of copepod development would have substantial effects on larval fish feeding, growth, and survival.

Myers et al. (1993) report that cod spawn about two months earlier on the Flemish Cap than on the Grand Banks at similar latitudes, adding support to observations that the Flemish Cap ecosystem is distinct from that of the Grand Banks.

3.7 NEKTON

Since the Terra Nova Development EIS was prepared, DFO has conducted large scale surveys of the offshore environment of Newfoundland and Labrador (including 3LNO). This section on nekton has been included to discuss the results of these surveys, much of which is at least generally relevant to the White Rose area. Nekton is defined here as those free-swimming marine organisms ranging in length from 10 to 200 mm. They include both invertebrate and vertebrate animals.

The surveys were conducted during late summer between 1994 and 1998 (Anderson and Dalley 1997) and again in 1999, but results from the latter are not yet available (J. Anderson, pers. comm.). They were initially designed to measure abundance of pre-recruit Atlantic cod and capelin during the pelagic juvenile fish stage. The upper 100 m of the water column was surveyed by plankton tow (bongo samplers) and a mid-water trawl was used to survey the 20 to 60-m layer of the water column.

Based on the 1994-1998 multi-species MPE trawl survey, Anderson et al. (1999) characterized the pelagic ecosystem of the study area shelf waters off Newfoundland as boreal (western half of Northern Grand Bank) and temperate (eastern half of Northern Grand Bank and entirety of Southern Grand Bank) (Figure 3.7-1). Anderson et al. (1999) described trends in distribution and abundance of dominant pelagic fish species during 1994 to 1998. All of these species are planktivores, feeding in the upper mixed layer, dependent on summer production of zooplankton. The dominant fish nekton in the boreal and temperate areas were capelin and sand lance, respectively. The capelin and sand lance were primarily one year and older.

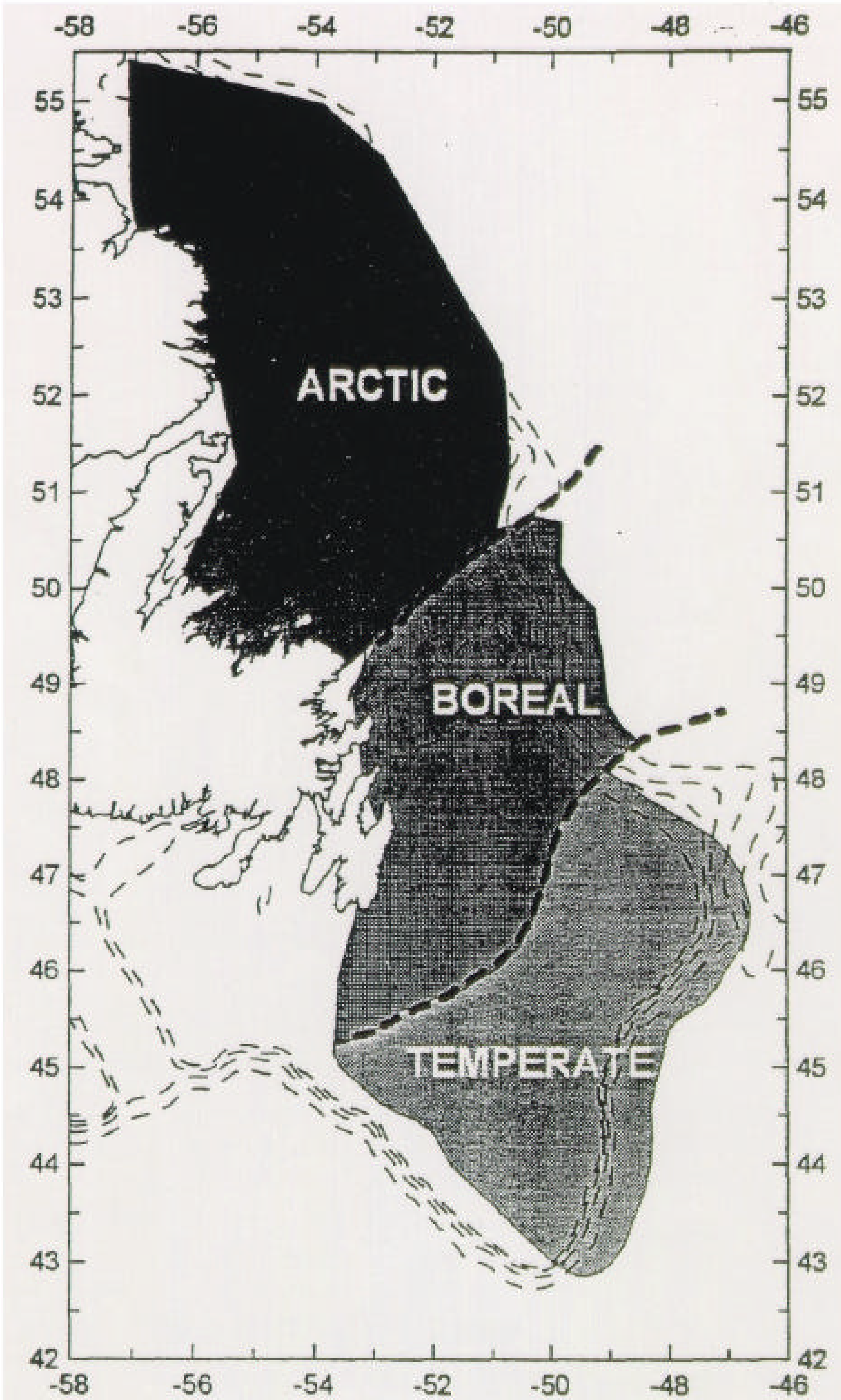
Since 1994, surface layer water temperatures in the ocean have been above normal. On the Grand Banks, there was a large increase in bottom warm water habitat in the spring of 1998. The order of magnitude increase in the production of young (0-group) fish on the Southern Grand Bank in 1998 occurred across several species, including capelin, Atlantic cod, American plaice and haddock. The large increase in fish production appeared to result from the migration of adults onto the Southern Grand Banks during spring of 1998, in response to warm bottom water temperatures.

Juvenile capelin were most abundant on the north slope of the Grand Banks, while sand lance dominated the south, including the eastern half of the Northern Grand Bank and the entire Southern Grand Bank. One-year-old capelin were only observed in small numbers on the Southern Grand Bank in 1994 and 1995, while two-year-old capelin were observed on the Southern Grand Bank only in 1998. Sand lance abundance was relatively low during 1994 to 1997, but underwent an order of magnitude increase in 1998.

On the Grand Banks in 1998, order of magnitude increases in abundance were also measured for Atlantic cod and American plaice, and haddock numbers were similar. All three species were distributed throughout the Southern Grand Bank and extended onto the Northern Grand Bank.

Since 1994, there has been a general decrease in the percentage area of the Grand Banks bottom covered by subzero (°C) water. Between 1991 and 1998, the percentage area with subzero temperatures fell from 70 percent to 15 percent. The percentage area covered by water temperatures 0 to 1°C increased from 20 percent in 1991 to 1993 to 40 percent in 1996 to 1998. During 1990 to 1992, percentage area covered by water temperature >1°C was approximately 10 percent and by 1998, this had increased to 50 percent. The 1998 spring value represents the largest area of relatively warm water on the Grand Banks since 1983 (Anderson and et al. 1999).

Figure 3.7–1 The Dominant Nekton Regimes in the Northwest Atlantic Pelagic Ecosystem



1401-39.cdr 23JUN00 Figure 3.7-1

Source: Anderson et al. (1999)

During 1994 to 1998, observed changes in the dominant pelagic fish species have been consistent with a warming ocean environment. These changes have included an expansion in geographical range and an increase in the production of young fish for boreal and temperate regime species. Presence of large numbers of adult Atlantic cod and haddock during the 1998 spring 3LNO bottom trawl survey (Northwest Atlantic Fisheries Centre unpubl. data) indicates that adults moved onto the Southern Grand Bank from areas to the west. Similarly, adult capelin (mostly spent) were caught on the Southern Grand Bank in 1998. The increased abundance of large sand lance in the absence of evidence of high year-class production in the area, is consistent with the migration of older sand lance onto the Southern Grand Bank in 1998.

Anderson et al. (1999) tentatively concluded that the large increase in abundance of fish on the Southern Grand Bank in 1998 was a result of favourable environmental conditions in spring that facilitated the migration of adult fish into the area to spawn. This was followed by a relatively high survival rate during egg and larval stages.

The following sections provide more detailed summaries of sample results during the MPE surveys conducted between 1994 and 1998 (Table 3.7-1).

3.7.1 1994 and 1995 Surveys

During 1994 and 1995, nekton biomass was greatest over the northeast Newfoundland Shelf and lowest both Inshore and over the Grand Banks. Juvenile Arctic cod were notably absent on the Grand Banks each year, although their distribution along the outer margins indicated a southward drift in the Labrador Current. In both 1994 and 1995, juvenile squid occurred on the Southern Grand Bank, but in lower abundances than on the northeast Newfoundland Shelf and off southern Labrador. During both years, juvenile Atlantic cod were distributed broadly throughout the inshore areas of 3L. There was also a distinct concentration sampled on the Southern Grand Bank in 1994. However, in 1995, juvenile cod were mostly absent from the Southern Grand Bank portion of the survey. Juvenile redfish occurred over the Southern Grand Bank each year as well as on the eastern slope of the Northern Grand Bank in 1995. In both 1994 and 1995, one-year-old capelin were distributed most abundantly over the Northern Grand Bank and throughout the Inshore area, but they were absent from the Southern Grand Bank. Juvenile Greenland halibut were absent on the Grand Banks in 1994 and 1995. Juvenile American plaice occurred in low abundances Inshore and on the Southern Grand Bank each year of the survey, but they occurred at only a couple of stations on the Northern Grand Bank.

Table 3.7–1 Locations of Occurrences of Various Vertebrate Nekton on the Grand Banks During Late Summer Surveys, 1994-1998

Survey Yr	Survey Area	Capelin	Atlantic cod	Sand lance	Squid	Redfish	American plaice	Yellowtail flounder	Witch flounder	White hake	Haddock	Greenland halibut
1994	Boreal: western 3L	*	*		*		*					
	Temperate: eastern 3L											
	Temperate: 3N	*			*							
	Temperate: 3O	*	*			*	*					
1995	Boreal: western 3L	*	*		*		*					
	Temperate: eastern 3L		*		*	*						
	Temperate: 3N	*	*		*	*						
	Temperate: 3O	*			*	*	*					
1996	Boreal: western 3L	*		*	*							
	Temperate: eastern 3L	*		*	*							
	Temperate: 3N		*	*	*			*		*		
	Temperate: 3O		*	*		*	*	*	*	*		
1997	Boreal: western 3L	*										
	Temperate: eastern 3L			*								
	Temperate: 3N	*		*						*		*
	Temperate: 3O					*				*		
1998	Boreal: western 3L	*	*	*						*	*	
	Temperate: eastern 3L	*		*								
	Temperate: 3N		*	*	*	*				*		*
	Temperate: 3O		*			*	*	*	*		*	
Sources: Anderson and Dalley 1997; Anderson et al. 1999; Dalley and Anderson 1997, 1998; Dalley et al. 1999												

Anderson and Dalley (1997) concluded that results from the 1994 and 1995 surveys suggested that the northeast Newfoundland Shelf might provide more favourable feeding conditions for planktivorous fishes than either the inshore or the Grand Banks. They felt that they were describing two contrasting shelf systems that lie adjacent to one another; the northeast Newfoundland Shelf as deep and cold with a high level of pelagic biomass, and the Grand Banks as shallow and warm with a relatively low level of pelagic biomass.

In summary, the pelagic community on the Grand Banks in 1994 and 1995 was predominantly composed of one- and two-year-old capelin.

3.7.2 1996 Surveys

Total wet weight of nekton in 1996, including and excluding jellyfish, was highly variable throughout the survey area. A decreasing north-to-south gradient was indicated by the 1996 data. Jellyfish were most abundant in the inshore areas. Capelin, predominantly one-year-olds, were distributed at various locations over the Northern Grand Bank and the highest concentrations of sand lance were also found on the Northern Grand Bank. A low concentration of Atlantic cod was found on the Southern Grand Bank during the 1996 survey. Arctic cod (*Boreogadus saida*) were distributed mainly in the inshore of Northern Grand Bank, along with a small area of distribution on the Southern Grand Bank. Redfish and white hake (*Urophycis tenuis*) had distinct distributions in southwestern Southern Grand Bank. There was a distinct distribution of squid on the Grand Banks in 1996, although concentrations were low compared to those north of the Grand Banks. American plaice, yellowtail and witch flounder were found on the Southeast Shoal of the Southern Grand Bank.

The mean wet nekton biomass, including jellyfish, was considerably less in 1996 than the preceding two years. Squid catches in 1996 were lower than in 1995 and 1994. One-year-old capelin catches were lower in 1996 compared to 1994. Conversely, white hake catches were higher in 1996.

3.7.3 1997 Surveys

The highest biomasses of nekton on the Grand Banks during the 1997 survey, including jellyfish, were found along the western side of the Northern Grand Bank and over almost the entire Southern Grand Bank. The Southern Grand Bank and the Northern Grand Bank ranked lowest in terms of total nekton biomass in the survey area. Jellyfish were most abundant Inshore.

Pelagic capelin (ages one and two) showed a stronger distribution in Northern Grand Bank in 1997 than in 1996. Distribution in 1997 spread onto part of the Southern Grand Bank. Distribution of sand lance in 1997 was similar to 1996 and was restricted primarily to the Grand Banks. Overall, sand lance catches were slightly higher on the Southern Grand Bank compared to the Northern Grand Bank.

Arctic cod catch rates were also low on the Grand Banks. Redfish distribution in 1997 was similar to that in 1996, in that one distinct area was found on the Southern Grand Bank. Overall during 1994 to 1997, the Southern Grand Bank showed the highest mean redfish catch rate and the Northern Grand Bank showed the lowest. The Southern Grand Bank also had the highest mean catch rate of white hake during the four-year period. There was a distinct 1997 distribution of juvenile wolffish on the Southern Grand Bank. Juvenile Greenland halibut were the only flatfish caught sporadically on the Grand Banks during the 1997 MPE survey.

3.7.4 1998 Surveys

The highest concentrations of total nekton biomass (including jellyfish) were found on the central portion of the Northern Grand Bank and portions of the northeast Newfoundland Shelf. For the first time in the MPE surveys, the north-to-south gradient of decreasing biomass was not evident. In 1998, the Inshore ranked highest in biomass while the Southern Grand Bank and the Northern Grand Bank ranked lowest. With jellyfish removed, the highest biomass was found on the central northeast shelf and at several other stations on the Grand Banks. The greatest biomass of jellyfish occurred in the Inshore and on the Northern Grand Bank.

One-and two-year-old capelin were more abundant and were distributed more widely in 1998 compared to 1997. The widest distribution of juvenile capelin was on the Northern Grand Bank and Inshore, while they were virtually absent from Southern Grand Bank. During the 1994 to 1998 period, highest juvenile capelin abundance occurred on the Northern Grand Bank, but was not substantially greater than the Inshore abundance.

Sand lance were 13 times more abundant in 1998 compared to 1997. Sand lance distribution in 1998 was primarily on the Grand Banks and extended to the Avalon Peninsula. As in 1997, the distribution of high catch rates at some stations near the edge of the Grand Banks suggested that the distribution extends beyond the area surveyed. The overall five-year mean catch rates were highest on the Northern Grand Bank which was not substantially higher than rates on the Southern Grand Bank. Abundance of sand lance in 1998 was considerably higher than the preceding four years.

For the first year since the survey began, relatively high catch rates of Arctic cod occurred on the Grand Banks. Overall, Arctic cod did not constitute much of the samples collected over the Grand Banks during 1994 to 1998. The highest redfish distribution again occurred on the southwestern Southern Grand Bank. Considering all five years, the Southern Grand Bank was the location of highest mean catch rate of redfish nekton while the Northern Grand Bank ranked lowest. White hake and squid catches in 1998 were again restricted to the Southern Grand Bank. During the five years of survey, the inshore and the Grand Banks ranked lowest in squid catch rate. Wolffish (*Anarhichas denticulatus*) catches increased on the shelf edge of the Northern Grand Bank in 1998.

Abundance of the four species of flatfish was relatively low during the five years of survey, often with sporadic distribution. American plaice catch rates in 1998 were highest on the Southern Grand Bank, compared to their inshore distribution in 1997. During the five years, the American plaice catch rate ranked highest Inshore, followed by the Southern Grand Bank. Greenland halibut catches in 1998 ranked lowest of all five years. Witch flounder were taken on the Southern Grand Bank in 1998 but were in low abundance. While only four juvenile yellowtail were taken in 1998 on the Southern Grand Bank, this area ranked highest during all years combined.

Pelagic 0-group haddock were observed in 1998 for the first time in the five years. They had a fairly extensive distribution on the Grand Banks, mostly on the southern portion, but also extending onto the Northern Grand Bank.

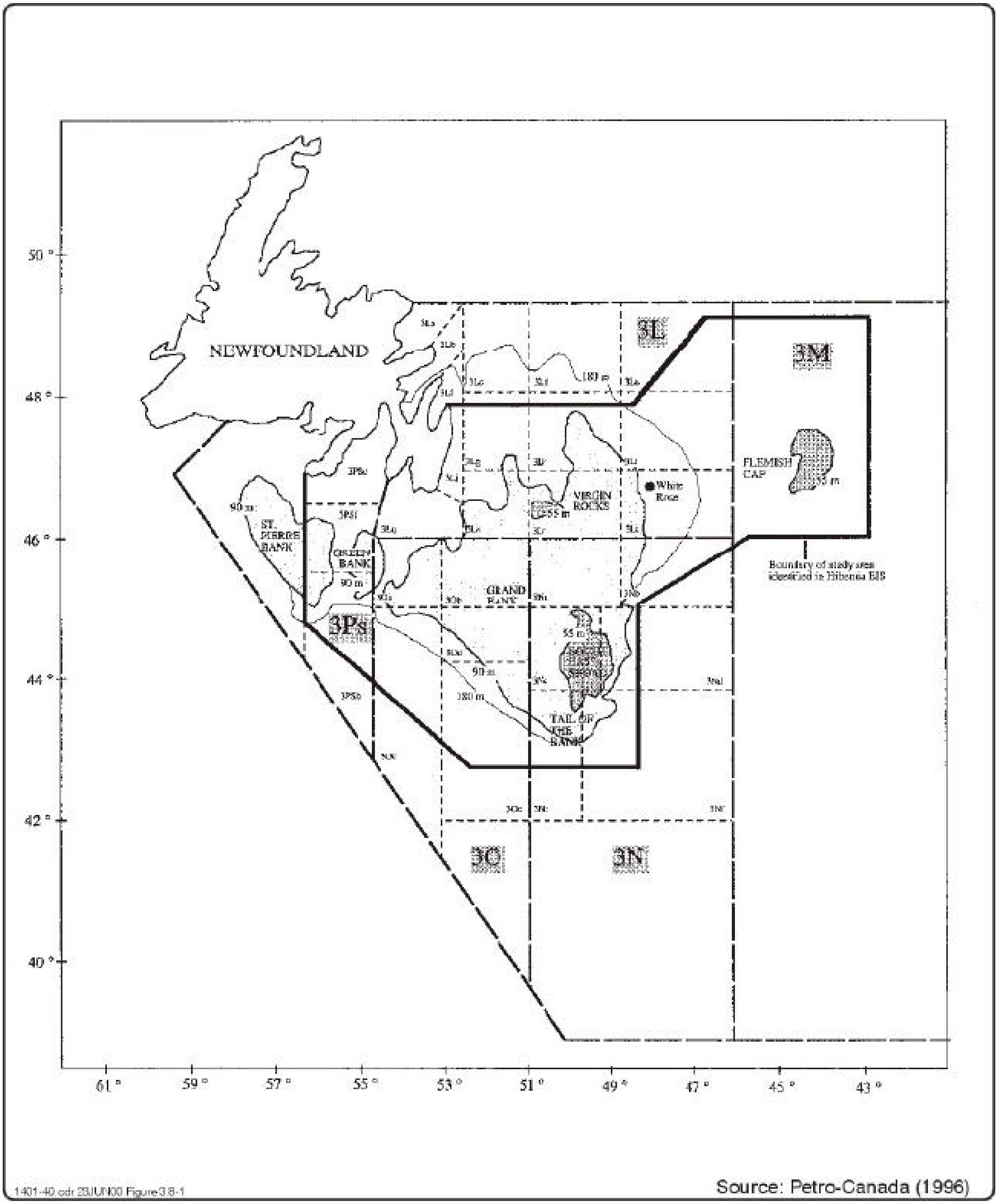
3.8 FISH

This section is based on published literature (primary publications and government publications) and unpublished data provided by DFO. Relevant Northwest Atlantic Fisheries Organization (NAFO) areas and major offshore plateaus of the Grand Banks are indicated in Figure 3.8-1. The White Rose site is located in NAFO Unit Area (UA) 3Lt.

Based on catch biomass landings at Newfoundland ports from 1992 to 1994, the invertebrate and fish species, which accounted for the highest catches in 3Lt and the seven adjacent NAFO UAs were as follows (Petro-Canada 1995):

- Iceland scallops;
- American plaice;
- Atlantic cod;
- Greenland halibut;
- snow crab;
- Stimpson's surf clam;
- bluefin tuna;
- yellowtail flounder;
- redfish;
- haddock;
- witch flounder;
- wolffish; and
- roundnose grenadier.

Figure 3.8–1 Study Area Relation to Major Offshore Plateaus on the Grand Banks and NAFO Division 3L, 3M, 3N and 3O and Subdivisions 3Ps. White Rose Location is indicated in NAFO Unit Area 3Lt



The remainder of this section will consider invertebrate and finfish species of NAFO Divisions 3LMNOPs that have been commercially important in the past, are presently important in an ongoing fishery, or are considered underused (non-traditional) species that may become more commercially important in the future.

Based on this brief scoping exercise using both Canadian and Newfoundland landings statistics for 1994 to 1998, particularly as they pertain to UA 3Lt and the seven adjacent UAs, the order of consideration for the most important species is as follows:

- snow crab;
- Iceland scallop;
- northern shrimp;
- Stimpson's surf clam;
- yellowtail flounder;
- porbeagle shark;
- Atlantic cod;
- Greenland halibut;
- American plaice; and
- Atlantic halibut.

Other species caught within the study area during 1994 to 1998 will also be discussed with respect to habitat, life history and stock status. The resource status discussions will be based primarily on research vessel (RV) surveys conducted at various times of the year. Emphasis will be placed on data collected since the preparation of the Terra Nova EIS (Petro-Canada 1995), although some information from that document will be included. The commercial aspects of the various fish species are described in Chapter 7 of the SEIS (Part Two).

3.8.1 Traditional Invertebrate and Finfish Commercial Species

3.8.1.1 Snow Crab

Habitat/Life History

Snow crab (*Chionoecetes opilio*) are commonly found in association with mud or sand-mud bottoms at temperatures ranging from -0.5 to 4.5°C. Young crabs are often found in shallow areas where the substrate is composed of more gravel. Seasonal distribution changes are not a factor because this species is essentially non-migratory, although in some areas there are indications that in deep water, snow crabs move from gravel bottom to mud bottom as they reach maturity (Bailey 1990).

Mating is thought to occur in late winter and spring and the eggs are carried by the female until the following year. Crab larvae hatch during the summer and remain free-swimmers at or near surface for approximately three months. They then descend through the water column and become benthic (Bailey 1990).

The snow crab diet includes clams, polychaete worms, brittle stars and various crustaceans. Primary predators of this crab include various groundfish, other snow crabs and seals (Dawe and Taylor 1999).

Status

Status assessment used data from multi-species bottom trawl surveys in NAFO Divisions 3LNO during the fall, 1995 to 1998. These surveys were conducted near the end of the fishing season and they sampled an extensive area of snow crab distribution. These surveys also attempted to sample the entire size range of the snow crabs. Males were virtually absent on the 3L slope of the continental shelf deeper than 800 m and across most of the shallow Southern Grand Bank in 3NO. Legal-sized crabs (>94 mm) predominated in catches at greatest depths near the shelf edge, smaller crabs predominated in shallower water, especially near the coast, and a mixture of sizes occurred at intermediate depths over most of the shelf in 3LNO (Dawe and Taylor 1999). Minimum legal size in the fishery was subsequently increased to 95 mm carpace width (Dawe and Taylor 2000).

During 1996-1998, it generally appeared that highest densities for large males were associated with offshore areas. For all size groups, the distribution of highest densities generally became fragmented and shifted to the north over the period of 1995 to 1998, particularly for the smallest males. Highest densities of largest (legal-sized) males appear to have shifted south as well, along the eastern 3LNO slope. The precision of biomass estimates for legal-sized crab in 1998 was highest for 3L (± 23 percent) and lowest for 3NO (> ± 70 percent) (Dawe et al. 1999).

Based on fall bottom-trawl surveys during 1995 to 1998, male snow crab, especially the larger ones, are relatively dense in NAFO unit area 3Lt. Densities of the smaller males (< 60 mm carapace width) in the 3Lt region appear to have decreased from 1995 to 1998 (Dawe et al. 1999).

3.8.1.2 Iceland Scallop

Habitat/Life History

In the Newfoundland area, Iceland scallops are normally found at depths from 55 to 200 m on hard bottom composed largely of sand, gravel, shell fragments and stones. Being filter feeders, they tend to be most abundant in areas with substantial water movements (Naidu 1997).

Iceland scallops in Newfoundland commence spawning around April/May, triggered perhaps by short-term variations in temperature. Larvae are planktonic for up to 10 weeks before settling out on substrates (Naidu 1997).

These bivalves are suspension feeders that filter water immediately above the sediment surface. Iceland scallops are prey for Atlantic cod, American plaice, yellowtail flounder and wolffish (Gilkinson and Gagnon 1991).

Status

Exploitation of Iceland scallop resources in Newfoundland has been largely based on short-term economics rather than on consideration of resource sustainability. The directed fishery for this species over the Grand Banks is relatively recent, having begun in earnest in 1993 (Naidu et al. 1995; 1996; 1998).

The White Rose area lies outside existing Iceland scallop TAC zones. That is to say, scallop aggregations with commercial potential are not present at the White Rose field.

TACs were put in place in 1994, with 1,000 tonnes for 3L (primarily in an area east of the Virgin Rocks in 3Lr) and 3,000 t for the Lilly and Carson Canyons in 3Nb and 3Nd. By 1996, declining catch rates to the north of the Canyons forced fleets to search for new aggregations. One was found on the southeast part of the 'Tail' in NAFO (UA) 3Nf. Subsequent surveys in this area indicated that only approximately 20 percent of area surveyed was suitable scallop bottom.

In November 1996, Fishery Products International (FPI) conducted an exploratory survey in the Flemish Cap area. Not one scallop was taken in the 102 tows conducted over the hard, rocky substrate bottom type, which is generally deemed unsuitable for scallops (Naidu et al. 1997).

3.8.1.3 Northern Shrimp

Habitat/Life History

The largest northern shrimp concentrations occur mainly on muddy to sandy-mud bottom within a temperature range of approximately 1 to 6°C. These concentrations are found in depressions on the Labrador and Scotian shelves at depths ranging from 150 to 500 m. It is generally recognized that the average size of shrimp increases with depth except when egg-bearing females migrate to shallower water. Young males are concentrated in shallow water, whereas older individuals are found in greater proportions in deeper water (Parsons and Fréchette 1989).

In eastern Canadian waters, shrimp spawning occurs during late summer and fall and eggs remain attached to the female until the following spring. Berried females move into shallower inshore areas in late autumn and winter. Upon hatching in the Inshore area during the spring, the larvae remain in the surface waters for a few months and then commence movement towards the bottom, where they remain during maturation (Parsons 1993).

In addition to the size/age related horizontal movements of northern shrimp, diel vertical migration is also performed by this species. During the night, large proportions of shrimp move off the bottom (up to 5 m above substrate), most probably for feeding purposes. Presumably, movement off the bottom is to search for pelagic crustaceans, which form a substantial part of their diet (Parsons and Fréchette 1989). Northern shrimp are preyed upon by a variety of finfish, but the two most important predators in the Grand Banks area are Atlantic cod and Greenland halibut.

Status

Most Division 3M northern shrimp status indicators evaluated in spring 1999 were evaluated as uncertain. Fishery data were uncertain mainly due to the changes in fishing pattern between years and developing technology. Research data were uncertain because they originated from surveys directed towards groundfish on the Flemish Cap, rather than shrimp-directed surveys. No estimates of current or future stock size were possible (Savard and Parsons 1999).

Data on northern shrimp in Division 3LNO have been collected each autumn since 1995 as part of the Canadian multi-species research surveys. Biomass and abundance indices resulting from these sruveys indicate that the resource has been increasing.

Data suggest that during 1993 and 1994, males underwent sex inversion at age five. Age of inversion decreased during the mid-1990s, but appears to have returned to age five in 1999.

3.8.1.4 Stimpson's Surf Clam

Other than limited distribution and abundance data from the Grand Banks, little information is available on the Stimpson's surf clam (*Mactromeris polynyma*), especially regarding its general biology and ecology. Based on Newfoundland landings catch data, this shallow-burrowing (within 15 cm of substrate surface) bivalve appears most concentrated in the south-central and southeastern portions of the Grand Banks (3N), in both plateau and slope regions.

3.8.1.5 Yellowtail Flounder

Habitat/Life History

Yellowtail flounder is distributed off Newfoundland across much of the Grand Banks within NAFO Divisions 3LNO and Subdivision 3Ps. These flounder commonly prefer sandy bottoms. Early research indicated dense concentrations on the central part of the Grand Banks in less than 100 m (Kulka 1999). Yellowtail flounder were tagged and released on the Southern Grand Bank from 1990 to 1993. The study concluded that juvenile yellowtail were relatively sedentary with low transport rates out of the nursery area. There was a trend of northward movement the longer the time between release and recapture but all fish remained within 3NO (Morgan and Walsh 1999).

Peak spawning of yellowtail flounder generally occurs in June and July at depths less than 100 m and bottom temperatures exceeding 2°C (Kulka 1999). Yellowtail are serial-batch bottom spawners with pelagic larvae that hatch within 4 to 15 days of spawning. It is believed that the larvae remain pelagic for a very short time relative to other fish species (Walsh 1992).

These flounder feed upon surficial and interstitial benthic macrofauna such as amphipods and polychaetes, as well as crustaceans (shrimp, cumaceans and isopods) and finfish (sand lance and capelin) (Scott and Scott 1988).

Status

The NAFO Fisheries Commission closed the Grand Bank to directed fishing for yellowtail in 1994. CPUE in the fishery and research survey biomass estimates had dropped steadily between 1985 and 1994 (Walsh et al. 1999). Stock assessments for yellowtail in 3LNO from 1994 to 1996 continued to indicate low biomass. Between 1995 and 1997, the only commercial catches of yellowtail on the Grand Banks occurred outside Canada's 322 km (200 nautical miles) limit. By 1997, stock size appeared to have increased since 1994 and in 1998, a limited fishery was re-instituted in 3NO only because 3L was historically an area of low yellowtail concentration.

Brodie et al. (1998) concluded that the contraction of the yellowtail flounder range to primarily the area west of the Southeast Shoal on the Southern Grand Bank was mainly a function of low stock size, which resulted from the increased fishing pressure in the mid to late 1980s.

Surveys during 1996 to 1998 have shown that the stock is more widely distributed than in the early 1990s but not as extensive as in earlier years. Based on seven additional surveys since the 1997 assessment, the current view is that the stock size has increased since 1994 (Walsh et al. 1998).

The Spanish conducted spring surveys on yellowtail in the Regulatory Area in 3NO during 1995 to 1998 (Durán et al. 1999). In 1997 and 1998, mainly small mature fish appeared in the survey area and were more concentrated than in previous years. These smaller fish were more abundant either because of a change in their distribution or because they belonged to a large year class.

3.8.1.6 Sharks

In summer and fall, when waters warm up, sharks from southern regions move into Canadian waters, presumably to feed. Various species of shark are known to occur on the Grand Banks.

The porbeagle shark (*Lamna nasus*) is a pelagic or littoral shark usually more common on continental shelves but sometimes occurring well offshore. It is also known to frequent inshore areas, including harbours. This species is more common in the Canadian region during the spring, summer and fall but it is occasionally caught on fishing banks during the winter months. It seems to prefer cool rather than cold waters and is usually found in temperatures below 16EC (Scott and Scott 1988).

The porbeagle is ovoviviparous, the young being retained within the brood chamber (oviduct) of the female. The young, 60 to 75 cm long, are born alive, one to five pups per female, usually in late summer in northwest Atlantic waters, although females with young may be found throughout the year (Scott and Scott 1988). The porbeagle shark feeds mainly on small pelagic schooling species such as herring, gaspereau, and mackerels but cod, white hake, red hake, haddock, cusk and squid are also eaten (Scott and Scott 1988).

Newfoundland landings of porbeagle shark during 1994 to 1998 were reported throughout the study area, in deeper water at and beyond the shelf edge, and over the central Grand Banks region.

The shortfin mako shark (*Isurus oxyrinchus*) is an extremely active animal seldom encountered in waters of temperatures below 16°C. Prey of this shark species include swordfish, mackerels, tunas and bonitos (Scott and Scott 1988). Most of the limited Newfoundland landings between 1994 and 1998 occurred from the southeast portions of UAs 3M and 3N, although some catches were made in the offshore regions of 3O and 3L.

Status

The porbeagle shark population in the northwest Atlantic is in a state of decline. Recent stock abundance estimates indicate that the population is approximately 15 to 20 percent of the size of the virgin population in the 1960s (Campana et al. 1999).

Shark species are by-catches of the Greenland halibut fishery being conducted by the Spanish in the Regulatory Area of 3LMNO. The proportion of shark by-catch in the total catch is small (it has never exceeded 4.7 percent) and is dominated by the retained black dogfish (*Centroscylliumm fabricii*). The most abundant discarded shark species is the boreal shark (*Somniosus microcephalus*). Since 1996, the proportion of total sharks as well as the retained proportion of black dogfish have increased. Black dogfish are most abundant in 3NO catches, while boreal sharks are most common to 3LM (Durán et al. 1999).

In Spanish surveys conducted during the spring in 3NO, black dogfish are the most abundant shark species, followed by the deepsea cat shark (*Apristurus* spp.) and the spiny dogfish (*Squalus acanthias*). Black dogfish and deepsea cat shark were caught mainly at depths greater than 500 m and the spiny dogfish were most abundant in shallower waters (200 to 500 m). Biomass estimates for all species increased between 1996 and 1998. Surveys in 3M indicated low shark biomass but sampling depths were less than in 3NO (Durán et al. 1999).

3.8.1.7 Atlantic Cod

Habitat/Life History

Generally, Atlantic cod inhabit cool-temperate to sub-Arctic waters from inshore regions to the edge of the Continental Shelf. In winter, cod traditionally concentrated along the northern and northeastern slopes of the Grand Bank below the cold core of the Labrador Current. Here they would spawn and feed on capelin and sand lance. In spring, schools of cod would migrate onto the shallower parts of the Grand Bank and disperse inshore and to the Southeast Shoal, apparently following capelin spawning migrations (Gomes 1993).

Spawning specifics of cod within the study area are variable, depending on location. In 3L, spawning can occur from February to September, while in 3NO and 3Ps, spawning generally peaks in April and May (Myers et al. 1993). Historically, cod eggs and early-stage larvae in the offshore have been concentrated along the shelf break of the Grand Banks, particularly in the more northern parts (Taggart et al. 1994). Other areas of observed cod spawning include southern shelf break of the Flemish Cap (3M) (Fitzpatrick and Miller 1979), the southwest and southeast shelf breaks in Southern Grand Bank (3NO) (Fitzpatrick and Miller 1979), the shelf break of the St. Pierre Bank (3Ps) (Fitzpatrick and Miller 1979), inshore regions of 3L and 3Ps (Hutchings et al. 1993) and on the interior areas of the Grand Banks (Hutchings et al. 1993; Rose 1993).

As fry, cod feed on copepods, amphipods, barnacle larvae and other small crustaceans. Juvenile and young adult cod continue to feed on crustaceans including euphausiids, mysids, northern shrimp, small lobsters and crabs. When this fish reaches an approximate length of 50 cm, its diet appears to switch to finfish, particularly capelin, sand lance, redfish and herring. Other finfish in its diet include alewives (*Alosa pseudoharengus*), Atlantic and Arctic cod, cunner (*Tautogolabrus adspersus*), flounders, haddock, hake (*Urophycis* spp.), mackerel, shannies (*Lumpanus*), snakeblenny (*Rumpenus lumpretaeformis*), sculpins and silversides (*Menidia menidia*) (Scott and Scott 1988). Being adapted to bottom feeding, cod tend to stay close to the bottom during the day, but move up into the water column at night.

Status

Status of the various cod stocks in the study area are based on all or some of the following sources; commercial by-catch, research bottom trawl surveys, pre-recruit surveys, acoustic studies, sentinel surveys, brief food fisheries, index fisheries in the inshore and offshore and tagging studies.

Division 2J+3KL

The most recent assessment of the 2J+3KL cod stock concluded that there was no indication of stock recovery in the offshore. Lilly et al. (1999) stated that the risk of fishing this stock at various catch levels cannot be quantified because the current stock size is poorly measured, but it is clear that the stock size remains low compared to levels in the 1980s. Spawning biomass has continued to decline, even after the imposition of the moratorium in 1992 (Lilly 1999). Status of cod in the inshore portion of this stock also remains uncertain. Abundance and biomass estimates of the inshore aggregations are unclear.

Atkinson et al. (1997) examined changes in distribution of the northern cod population between 1981 to 1993 and found that the area occupied by the population was positively correlated with stock abundance. The observed stock decline was associated with a shrinkage of occupied range.

Anderson et al. (1999) reported that cod larval hatching dates in southern 3L were earlier and spanned a longer time period in 1998 compared to 1994 to 1997. Larval hatching in southern 3L occurred from late April until late July and peak spawning in 1998 was thought to have occurred in April.

Division 3NO

The 3NO cod stock occupies the southern part of the Grand Bank. Fish are normally distributed over the shallow parts of the bank in summer, particularly around the Southeast Shoal area in 3N. In winter, when cooling occurs, the fish generally move to the slopes of the bank. There has been a commercial fishery moratorium on this stock both inside and outside the 322 km (200 nautical miles) limit since 1994 (Stansbury et al. 1999).

The 1998 spring and fall research vessel surveys indicated that the current size of this stock remains at a low level but has shown a slight increase. Low spawning biomass, low recruitment and high total mortality make for poor prospects regarding stock recovery in the medium term. In 1998, 75 percent of the estimated biomass of the 3NO stock was found in three sampling strata in the western region of 3O. The biomass estimates for 3O from both spring and fall surveys have both increased slightly in 1998 (Stansbury et al. 1999).

Anderson et al. (1999) reported that cod larval hatching dates in 3NO were earlier and spanned a longer time period in 1998 compared to 1994 to 1997. Larval hatching in 3NO occurred from late April until late July and peak spawning in 1998 was thought to have occurred in April. The relatively large year-class measured on the Southern Grand Bank in 1998 appears to be a positive response by Atlantic cod to a warmer environment.

Recent modelling suggests that changes in productivity of the stock could have a major effect on the dynamics of the stock in future years and that recovery time will depend on which recruitment process prevails in the future (Rivard et al. 1999a). Results also suggested that fishing mortalities in excess of by-catch levels observed in recent years could increase the recovery time considerably.

Division 3M (Flemish Cap)

According to Vázquez et al. (1999), the present status of the 3M cod stock can be qualified as ‘in collapse’. There has been a steady decline in reported catches by non-Canadian fishers since 1994. Vázquez et al. (1999) reported that estimated cod biomass on the Flemish Cap declined after 1993 to the lowest ever seen.

Division 3Ps

This stock were originally thought to be comprised of fish that inhabit the outer slopes of St. Pierre Bank in the winter and migrate to the top of the Bank and south coast of Newfoundland in the summer. However, there is evidence that stock structure is much more complex (Brattey et al. 1999).

The estimated stock biomass in 3Ps, as of early 1999, has increased since the moratorium was imposed in 1992. Spawning biomass has also increased substantially and is currently similar to estimates in 1983 (Brattey 1999).

3.8.1.8 Greenland Halibut

Habitat/Life History

Also known in Canada as turbot, Greenland halibut (*Rheinhardtius hippoglossoides*) is a deepwater flatfish found in the North Atlantic Ocean. During the 1990s, this species has become the target of the most substantial groundfish fishery in the northwest Atlantic.

Greenland halibut are thought to spawn mainly in winter and early spring in the Davis Strait at depths of 600 to 1,000 m, although fish in spawning condition have been observed elsewhere, including the Flemish Cap region. Soon after hatching, Greenland halibut larvae ascend to within approximately 30 m of the ocean surface and remain there until attaining approximately 70 mm in length. As it grows, the halibut descends to greater depth. The Greenland halibut appears not to associate itself with the bottom as closely as other flatfish (Scott and Scott 1988).

This species is a bathypelagic predator with a wide prey selection. Prey taken during peak feeding in summer and fall include capelin, Atlantic cod, Arctic cod, roundnose grenadier, redfish, sand lance, and various crustaceans including northern shrimp, and cephalopods. Benthic invertebrates have also been identified as diet components of Greenland halibut (Scott and Scott 1988).

Status

During recent years, assessment of the Greenland halibut stock in 3KLMNO was based primarily on the interpretation of research vessel and CPUE indices. Biomass of fish larger than 35 cm was still below average in 1998 but increasing slowly. The number of older, mature fish in the research surveys remains low and spawning stock biomass estimates remain uncertain (Brodie et al. 1999). There has also been a distributional shift with a movement of fish into the Flemish Pass area on the border of Divisions 3L and 3M (Morgan and Bowering 1997). Junquera et al. (1998) specified the decline in Greenland halibut of 10+ years, which corresponds to the female age at 50 percent maturity.

During the 1997 fall research vessel surveys, the highest catches of Greenland halibut occurred in eastern 3L along the slope of the 'Nose' and in the Flemish Pass. This area is just east of White Rose. Other areas where relatively high catches occurred include the northeast slope of the Northern Grand Bank (3L), the southeast slope of the Southern Grand Bank (3N), the western slope of the Flemish Cap (3M), and the southwest slope of the Southern Grand Bank (3O) (Gundersen and Brodie 1999).

3.8.1.9 American Plaice

Habitat/Life History

American plaice inhabit a wide range of depths (30 to 700+ m) and water temperatures (0 to 13°C). They seem to prefer fine sand or mud bottoms. Spawning generally occurs in the spring with fish on the Flemish Cap spawning before those on the Grand Banks. The larvae hatch from the planktonic eggs within two weeks of spawning when water temperatures are approximately 5°C (Scott and Scott 1988).

Nursery areas for this species have been identified on the northern and northeastern slopes of the Grand Banks (3L), the southern end of the Banks (3NO), Whale Deep area of 3O, and the southwestern slope of the Grand Banks (Walsh 1991; 1994).

Reported benthic invertebrate and fish prey of American plaice include brittlestars, polychaetes, bivalve molluscs, sand lance, capelin and sculpin. Small pelagic crustaceans such as hyperiids have also been found in diet analysis of American plaice. Feeding is generally most intense during late spring and summer, dropping off to almost nil by mid-winter. American plaice have very adaptive feeding habits in that their prey spectrum is wide and they can temporally shift feeding in accordance with prey availability.

Status

In 3LNO, the American plaice stock reached very low levels in the early 1990s. There has not been a directed fishery in 3LNO since 1993. Canadian spring surveys showed a large decline in abundance and biomass from the mid to late 1980s until 1998, when estimated biomass was approximately 14 percent of that of the mid-1980s. The fall survey has indicated similar trends. Latest results of the fall survey indicated an estimated biomass of approximately 30 percent of that in 1990 (Morgan et al. 1999).

In 1998, an industry-sponsored survey was conducted for American plaice in 3LNO. This survey and the DFO fall survey showed similar distribution of the species. Plaice were widely distributed throughout 3LNO but most abundant in southern and southwestern 3NO (Atkinson et al. 1999). The 1998 Canadian spring survey indicated areas of highest abundance and biomass at the shelf break on the 3L and 3N border (southern 'Nose') and in 3O (southwestern Southern Grand Bank). Biomass and abundance estimates at White Rose were minimal. The European Union-Spain survey in the Regulatory Area of 3NO has shown a steady increase in abundance and biomass since 1997 (Paz and Durán 1999; Vázquez 1999).

Modelling was used to evaluate recovery time for American plaice in 3LNO under various by-catch levels. These simulations concluded that changes in the productivity of the stock could have a major effect on the dynamics of the stock in future years, and that recovery time will depend upon which recruitment process prevails in the future and upon removals control (Rivard et al. 1999b).

On the Flemish Cap, the stock occurs mainly at depths shallower than 600 m. A series of research surveys by the European Union since 1988 have indicated a decreasing trend in abundance and biomass. Results in 1997 and 1998 showed the lowest levels in the time series (E. de Cárdenas 1999). The estimated spawning biomass of American plaice on the Flemish Cap has steadily decreased since 1994. By 1998, it was only 24 percent of the 1988 estimate. Despite low commercial catches since 1992, survey data indicate that this stock is at a very low level and shows no signs of recovery.

3.8.1.10 Atlantic Halibut

Habitat/Life History

Atlantic halibut (*Hippoglossus hippoglossus*), the largest of the flatfishes, ranges widely over Canada's Atlantic fishing grounds. It tends to move from shallower waters (< 37 m) into deeper water in winter, returning to the shallower areas in summer. Young halibut appear most concentrated in shallow waters (37 to 55 m), whereas large mature halibut inhabit deeper areas (165 to 230 m) (Scott and Scott 1988).

Atlantic halibut spawn in late winter/early spring in most of the Canadian area, probably at depths > 180 m. These voracious eaters prey upon invertebrates such as crabs, shrimp and euphausiids when young (30 cm length) and switch to fish as they grow larger (Scott and Scott 1988).

Status

In general, commercially-caught halibut are most frequently taken at depths of 200 to 300 m in water temperatures ranging from 3 to 9°C. Within the study area, most catches are made along the shelf edge and at the Flemish Cap. Newfoundland landings data for 1994 to 1998 indicate most catches from 3NOPs, although some Atlantic halibut were taken in Division 3L.

3.8.1.11 Redfish

There are three species of redfish that have been fished in the study area. In 3LN, the deep-sea redfish (*S. mentella*) and the Acadian redfish (*S. fasciatus*) have been targeted in the fishery (Power and Maddock-Parsons 1998); in 3M, these two species and the golden redfish (*S. marinus)* have been fished. Due to external resemblance, the deep-sea redfish and the Acadian redfish are commonly designated as beaked redfish (Ávila de Melo et al. 1998).

Habitat/Life History

Deep-sea redfish are most abundant at depths greater than 300 m, while the other two species appear to prefer shallower waters of less than 400 m. Each of the three species demonstrates both a pelagic and demersal behaviour, which results in inter-annual distributional variability (Ávila de Melo et al. 1998).

Redfish are ovoviviparous (that is, give birth to living young) and generally spawn in the March to July period. Timing of spawning varies between different locations on the Grand Banks, depending on water depth and water temperature.

Redfish feed on a variety of small invertebrates and fish. The two beaked redfish species appear to feed on a wider spectrum of prey than the golden redfish but zooplankton such as copepods, hyperiids, shrimp, mysids and euphausiids are evident in the diets of all three redfish species. Predators of redfish include Greenland halibut, Atlantic cod and swordfish (*Xiphias gladius*).

Status

Division 3LN

Since 1987, catches declined steadily up to 1996, with a slight catch increase in 1998. A moratorium on directed fishing for redfish was implemented in 1998 and 1999, and as a result, recent catches have been the result of by-catch from the Greenland halibut fishery. During the 1990s, fishing effort was concentrated in an area southwest of the Flemish Cap at the border of 3LMN (Power and Maddock-Parsons 1999).

Assessment of redfish in 3LN is difficult considering the inter-annual variability associated with survey data. Nevertheless, estimates from recent surveys are considerably lower than those from the 1980s, indicating a reduced and low stock size. Poor recruitment has persisted in 3LN since the 1980s, making stock recovery in the short or intermediate term unlikely (Power and Maddock-Parsons 1999).

During 1995 to 1998, Canadian spring and autumn research vessel surveys in 3L found highest abundance and biomass at depths greater than 366 m on the outer shelf regions of the northeast ‘Nose’, between the ‘Nose’ and the Flemish Cap, and of the southeast ‘Nose’.

Division 3M.

European Union surveys in 3M during 1988 to 1998 have indicated variable biomass and abundance estimates for beaked redfish. Both biomass and abundance estimates have shown a decreasing trend since 1992. Estimated spawning biomass of beaked redfish in 3M has shown a decreasing trend since 1988 (Ávila de Melo et al. 1999).

European Union surveys in 3M during 1988 to 1998 have indicated variable biomass and abundance estimates for golden redfish. Both biomass and abundance estimates peaked in 1997 and then dropped substantially in 1998. No trend was obvious during the 1988 to 1998 period. Estimated spawning biomass of beaked redfish in 3M has also been variable during the 11-yr period. Estimated spawning biomass peaked in 1994 and 1997 (Ávila de Melo et al. 1999).

Division 3O

Spring and fall groundfish surveys suggest that the 3O redfish stock may have increased since the early 1990s, stabilizing since 1994. The low index in 1997 is considered an anomaly. Both spring and fall surveys in 1999 support this pattern. One area of concern regards the minimal sign of size groups smaller than 17 cm during recent surveys. This has occurred despite the use of the Compelen trawl, which is very effective at catching small redfish (Power 1999a).

3.8.1.12 Capelin

Habitat/Life History

Capelin is a small pelagic schooling species with a short life span and variable recruitment. These latter two characteristics offer great potential for frequent and dramatic changes in mature biomass (Nakashima 1999).

Capelin diet includes planktonic fauna such as euphausiids, copepods and amphipods. Feeding is seasonal and intensifies in late winter and early spring during the prespawning period. Feeding intensity declines as spawning season approaches and virtually ceases during spawning (Scott and Scott 1988). Being prey for a diverse group of predators, capelin is considered a keystone species of the Grand Banks food web. Primary predators of adult capelin include Atlantic cod, Greenland halibut, haddock, Atlantic salmon (*Salmo salar*), seals, whales and seabirds (Nakashima 1999). Larval and juvenile capelin are important as food to Atlantic herring, flounders, dogfish, sculpins (*Artediellus* spp.) and eelpout (Petro-Canada 1996).

The Northern Grand Bank and northeast Newfoundland Shelf are considered to be major nursery areas for capelin. At maturity, schools of adult capelin migrate inshore to spawn on and near Newfoundland gravel beaches during June and July. Timing of inshore spawning was delayed during the 1990s and this trend has continued. Later spawning has been correlated with colder water and smaller fish size. After hatching, the larvae leave the beach gravel and are carried out of the bays and out to the nursery areas by surface currents (Nakashima 1999).

Some capelin are not beach spawners but remain offshore to spawn, specifically on the Southeast Shoal. Suitable substrate and water temperatures at the Shoal provide ideal spawning habitat for capelin.

Status

In the northwest Atlantic, five stocks of capelin have been identified on the basis of spawning times, patterns of fishery and biological traits. The three that are within the boundaries of the study area include those of the Northern Grand Bank and Avalon in Division 3L; those of the Southern Grand Bank in Division 3NO; and those of the St. Pierre Bank in Subdivision 3Ps.

Evidence clearly demonstrates that changes have occurred in the behaviour and biology of capelin inshore on the northeast coast of Newfoundland since 1991, compared to the 1980s. Offshore changes have also been observed. The offshore distribution of capelin has expanded to include the Flemish Cap in Division 3M (Frank et al. 1996). A decline in biomass was also reported from annual offshore acoustic surveys by Canada and Russia during the early 1990s. These surveys also indicated disruptions in capelin diurnal behaviour, affecting vertical distribution patterns (Nakashima 1996).

During offshore fall surveys in the 1980s, capelin were widely distributed from 2J to 3L, with a gradient of larger to smaller capelin from north to south. In the early to mid-1990s, few capelin have been observed in 2J and northern 3K, while most have been detected in southeast 3K and northern 3L. The same size trend described above appeared to exist. Now the capelin distribution appears to be changing to more closely resemble the distribution observed in the 1980s. In 1997 and 1998, capelin appeared more extensively in western 3K and southern 2J. Capelin bycatch in spring groundfish surveys in 3L showed a broad distribution in 1996-1998, similar to distributions seen in the mid to late 1980s.

The 1998 surveys detected ripe adult capelin and recently hatched larvae in the Southeast Shoal area in 3LNO, reminiscent of distributions in 1980s. These are perhaps first indicators that capelin may be exhibiting distributions and behaviour considered more typical than previously observed in the early 1990s. These changes are also coincident with general warming of seawater in the Newfoundland region.

Capelin appeared on the Flemish Cap (3M) during 1990s as by-catch in groundfish surveys and the shrimp fishery. Historically, capelin were rare in this area and their occurrence here seemed to coincide with increased amounts of cold water. The average size of capelin declined during the 1990s and has remained small. Offshore distribution changes appear linked to water temperature changes. Below normal temperatures in the early 1990s may have caused dramatic shifts in distribution and the change back to the more normal situation is perhaps in response to a warming trend.

Other observed unusual characteristics of capelin biology during the 1990s include:

- increase in relative proportion of night spawning;
- changes in physical structure of the otoliths, causing problems with aging;
- increased incidence of females with ovaries full of unspawned eggs in the fall; and
- consistent and relatively high proportion of spent females in the fall since 1992.

Since 1994, three series of indicators were combined in a model (Nakashima 1999) to provide relative estimates of year-class strength:

- aerial survey index;
- purse seine catch rate index; and
- egg deposition index.

The 1998 aerial survey index was lower than 1997 and below the 1990 to 1998 average. The 1998 egg deposition rate was highest in the 1990 to 1998 series. Catch rate data from purse seines and traps in 1997 and 1998 are not considered comparable to catch rate data from 1980s and, therefore, were not used in the model.

Recruitment index was calculated by the model using results from surveys for larvae and one-year old fish. Combining all indicators into one model indicated that the 1990s might be characterized as a period of relatively strong year classes compared to the 1980s. However, there are large statistical uncertainties associated with the mathematical modelling.

Both the aerial survey and egg deposition studies (fishery-independent indices) have been reduced in geographical coverage and/or intensity. It is unlikely that future assessments of capelin will be improved at the current level of research activity (Nakashima 1999).

According to a 13-index modelling exercise to examine 3KL capelin resource status, year-classes during the 1990s have been above average and slightly higher than year-classes from the 1980s. Many uncertainties in the assessment of this capelin stock remain (Carscadden 2000).

3.8.1.13 Swordfish

Swordfish (*Xiphias gladius*) usually enter Canadian waters in late spring/early summer and remain until mid to late fall. This species moves through a large depth range (surface to 500+ m), generally migrating to surface waters at night in response to lower light levels. Swordfish do not reproduce in Canadian waters. They are thought to spawn throughout the year in the Caribbean Sea, Gulf of Mexico and waters off Florida. Swordfish are probably opportunistic feeders. The most commonly occurring prey in swordfish taken in Canadian waters includes shortfin squid, Atlantic mackerel, silver hake, redfish, herring and lanternfishes (Scott and Scott 1988).

3.8.1.14 Bluefin Tuna

Bluefin tuna (*Thunnus thynnus*) may be present in Canadian waters from early summer to early fall, feeding at depths of 25 to 180 m. They do not spawn in Canadian waters. During this time they are eating primarily pelagic species such as herring, capelin, mackerel and squid. Other prey may include saury, lanternfishes and hake (Scott and Scott 1988).

3.8.1.15 Bigeye Tuna

Bigeye tuna (*Thunnus obesus*) generally occupy the more temperate waters in the western North Atlantic. Catches of this species tend to be higher in areas where water temperatures exceed 8°C (Scott and Scott 1988).

3.8.1.16 American Lobster

American lobsters (*Homerus americanus*) are distributed nearshore around the island of Newfoundland. Newfoundland lobster fishing areas (LFAs) 8 and 9 are within the study area and extend from Cape St. Francis to Cape St. Mary's. Declines in landings in recent years have been substantial enough in certain areas to raise concerns regarding the possibility of a new long-term downward trend (Ennis 1998).

3.8.1.17 Atlantic Salmon

The main function of sea migration by Atlantic salmon (*Salmo salar*) is known to be feeding. Small salmon feed mainly on euphausiids, amphipods and decapods while the larger salmon feed on herring, alewives, smelt, capelin, small mackerel, sandlance and small cod. While at sea, Atlantic salmon are prey for seals, sharks, pollock, tuna and various sea birds (Scott and Scott 1988).

The distribution, abundance and ecology of salmon at sea is not well known, especially for the post-smolt stage. Directed research programs on salmon at sea are essential to help explain the significant decline in Atlantic salmon abundance since the late 1970s (Porter 1999). Salmon migration in offshore areas is generally thought to occur clockwise over the northeast Newfoundland shelf and southern Grand Banks. Research suggests an extensive spring migration in surface waters along the slope regions. There is some belief that large numbers of salmon may overwinter in deep water east of the Grand Banks (Mobil 1985). Reddin (1985) reported that exploratory fishing with surface gillnets on the Grand Banks and eastward of the Bank over oceanic depths in 1979 and 1980 implied that the eastern and southern Grand Banks region may represent not only the route by which maturing salmon migrate from the Labrador Sea to home rivers in eastern Canada, but also a major feeding and overwintering area.

3.8.1.18 Witch Flounder

Habitat/Life History

The spawning peak of witch flounder in Division 3L occurs March to May and may continue through to July. In 3NO, this species spawns principally in July and August, and in 3Ps, witch flounder spawn at highest intensity between January and March. Spawning generally occurs at depths greater than 500 m along the shelf slopes and in deepwater channels (Scott and Scott 1988).

The principal diet of witch flounder includes polychaetes, amphipods, small fish and molluscs such as bivalves and gastropods (Scott and Scott 1988).

Status

Division 2J+3KL

The current stock size in these divisions is extremely low compared to historical levels. Current indices based on research surveys place the stock at approximately 5 percent of the average in the early 1980s. For all three divisions combined, the biomass index decreased from 1984 to 1995. Biomass estimates in 3L declined in

1995. Witch flounder concentrations now appear to be located only along the deep continental slope area, especially in 3L, both inside and outside the 322 km (200 nautical miles) limit (Bowering 1999a).

Division 3NO

Biomass and abundance estimates from research vessel surveys for witch flounder in Division 3N have remained at very low levels throughout the period since 1984. In 3O, where most of the stock resides, there has also been a declining trend in stock size. Estimates in 1998 were the lowest since those in 1984 (Bowering 1999b).

Divisions 3Ps

Research vessel survey results suggest that the recent biomass levels may be about two-thirds of that of the late 1980s and early 1990s. Most fish caught during recent surveys were found along the slope regions and in deep water channels (Bowering 1999c).

3.8.1.19 Short-Finned Squid

Habitat/Life History

The short-finned squid (*Illex illecebrosus*) is a pelagic cephalopod with a lifespan of only 1 to 1.5 years. There are indications that squid move off all shelf areas during late fall. Dawe et al. (1998) showed that squid move onto the slope of the continental shelf in NAFO Subarea 3 (particularly the southwest slope of Southern Grand Bank) during May to June and appear inshore in the Newfoundland area as early as July, when near-shore bottom temperatures exceed 5°C. This inshore migration appears to be linked to food availability.

Crustaceans comprise the dominant component of the diet of smaller juvenile squid, while fish such as cod, capelin, herring, redfish and other squid seem more important to the diet of adult squid. Predators of squid include pilot whales (*Globicephala melanena*), cod, haddock, pollock (*Pollachius virens*), red hake (*Urophycis chuss*) and silver hake (*Merluccisu bilinearis*) (Black et al. 1987).

It is thought that short-finned squid spawn in the Cape Hatteras area in late fall and early winter. Egg masses, and subsequently larvae and juveniles, passively drift northward in the Gulf Stream, sometimes reaching the Grand Banks by late spring or early summer. By summer, the juveniles commence their inshore migration. Squid leave the inshore area to begin southward spawning movement around November.

Based on a review of the biology and population dynamics of short-finned squid in the northwest Atlantic Ocean (Dawe and Hendrickson 1998), this species is now considered to constitute a unit stock throughout its range in NAFO Subareas 2 to 6.

Status

Sufficient spawner escape is particularly important for an annual species such as short-finned squid in that recruitment is highly variable and overfishing during a year of poor recruitment could lead to stock collapse (Hendrickson 1999).

3.8.1.20 Haddock

Habitat/Life History

Traditionally, haddock inhabit cool temperate waters from inshore areas to the edge of the continental shelf, over hard, smooth sand or gravel bottoms. Their distribution varies seasonally, with dispersal over the shelf areas in summer and return to deeper water in the winter (Scott and Scott 1988).

Haddock are primarily bottom feeders. Haddock under 50 cm long appear to prefer crustaceans such as amphipods, pandalid shrimp and hermit crabs, as well as echinoderms, molluscs and annelids. The diet of haddock larger than 50 cm includes more fish such as sand lance, capelin, silver hake, herring and argentines (*Argentina silus*) (Scott and Scott 1988).

Status

Directed fishery for haddock was stopped in 1994 and the 3LNO stock has shown no signs of recovery. Recent research vessel surveys have found very few haddock and indicate that recent year classes are weak and show poor prospects of stock improvement in the near future (FRCC 1998).

3.8.1.21 Grenadier

Two species of grenadier are considered in this section on fish of the Grand Banks. They are the roughhead grenadier (*Macrourus berglax*) and the roundnose grenadier (*Coryphaenoides rupestris*).

Habitat/Life History

Roughhead and roundnose grenadier are abundant and widespread fish species in the North Atlantic and are typically found both on the shelf and on the continental slope, predominantly at depths from 400 to 1,200 m (Murua et al. 1999; Power 1999b).

Grand Bank roughhead grenadier are thought to spawn on the southern and southeastern slopes of the Southern Grand Bank, although it has been reported that roundnose grenadier spawning occurs near Iceland and that the eggs and larvae are carried to the Grand Banks by water currents (Scott and Scott 1988).

Roughhead grenadier feed on a variety of benthic invertebrates including bivalve molluscs, shrimp, seastars and polychaetes. Certain finfish also comprise part of the diet of the larger roughhead grenadier. Larger fish, including cod, are thought to be the primary predators of this species.

Roundnose grenadier feed seasonally, with peak intensity occurring in fall and winter. Diet items include lanternfish (*Benthosema glaciale*), amphipods and mysids. Greenland halibut and redfish appear to be the primary predators of roundnose grenadier.

Status

The best source for the assessment of the roughhead grenadier stock in Subareas 2 and 3 is the Canadian Fall Survey Series. Presently, the highest part of this species' biomass is found in 3L and 3N, at depths between 1,000 and 1,200 m. Since the early 1990s, it seems that the main part of the stock has shifted from northern divisions (2J and 3K) to 3LN and inhabit greater depths (Junquera et al. 1999). Murua et al. (1999) describes the roughhead grenadier population on the Flemish Cap based on European Union bottom trawl surveys since 1988.

3.8.1.22 Atlantic Herring

There are two Atlantic herring stocks along the Newfoundland coast that are distributed within the study area; 1) Conception Bay - Southern Shore, and 2) St. Mary's Bay - Placentia Bay.

Habitat/Life History

Atlantic herring is a pelagic species occurring both in shallow inshore waters and in offshore areas. In the offshore, herring can be found at depths ranging from surface to 200 m.

The two stocks within the study area are characterized by the predominance of spring-spawning herring (Wheeler 1998). The spawning occurs in inshore shallows and the eggs remain on the bottom until larvae hatch and move into the water column. Herring larvae are light sensitive and commonly migrate vertically in response to ambient light levels (Scott and Scott 1988).

Herring are daytime visual feeders and use their long, well-developed gill rakers to filter plankton out of the water. Young herring feed primarily on phytoplankton and then switch to zooplankton and ichthyoplankton as they grow larger. Adult herring prey include copepods, euphausiids, pteropods, mollusc larvae, sand lance eggs and larvae, capelin and other herring. Predators of this species include many finfish (for example, skates (*Raja* spp.), salmon, cod, hake), marine birds and marine mammals.

Status

Commercial amounts of herring have been essentially absent from the Conception Bay-Southern Shore area in recent years. Research gill net catch rates decreased by 70 percent from 1996 to 1998 in St. Mary's Bay-Placentia Bay, while commercial gill net catch rates decreased by 32 percent over the same period. This stock is at a moderate level compared to peak levels in the early 1970s (Wheeler 1998).

3.8.2 Non-Traditional Groundfish Species

This section will consider fish species that have been identified during the last few years as non-traditional, potentially commercial groundfish species on the Grand Banks. They include various skate species, particularly the thorny skate (*Raja radiata*), Atlantic or striped wolffish (*Anarhichas lupus*), spotted wolffish (*Anarhichas minor*), monkfish or goosefish (*Lophius americanus*), white hake (*Urophycis tenuis*) and winter flounder (*Pleuronectes americanus*).

3.8.2.1 Skates

Habitat/Life History

Thorny skate, the most common of the numerous skate species in waters around Newfoundland, are widely distributed in depths ranging from 20 to over 1,500 m, and at temperatures from -1.4 to 6.0 °C. These fish have been found on both soft and hard substrates. Spawning appears to occur year round on the Grand Banks, throughout the general area of distribution. Thorny skate may deposit up to 40 egg cases in a single year, each case containing a single embryo (Kulka 1998a).

Thorny skate diet includes polychaetes, amphipods, decapods and fish (redfish, sand lance and haddock).

Status

Based on research trawl survey data collected between 1951 to 1995, thorny skate was the most common skate species (> 90 percent of catch) caught in research surveys on the Grand Banks. The second most common skate species was the smooth skate (*Raja senta*), which comprised approximately 5 percent of the skate catch. When considering data from commercial gear, thorny skate made up 81 percent of the skate catch, followed by spinytail skate (*Raja spinicauda*) at 10 percent, barndoor skate (*Raja laevis*) at 4 percent, smooth skate at 2 percent and winter skate (*Raja ocellata*) at 1 percent. Combined, all skate comprised about 1 percent of total commercial catches using various gear types (Kulka et al. 1996).

Research vessel survey data since 1991 indicate that the higher concentrations of thorny skate have occurred mainly south of 47°N along the outer shelf of the Grand Banks. There has also been a reduction in thorny skate density on the 'Tail' of the Grand Bank outside the 322 km (200 nautical miles) limit. Both research vessel and commercial data show that considerable shifts have taken place in the distribution of thorny skate, especially since 1990 (Kulka et al. 1996).

Aside from an increase in the proportion of mature fish caught during recent research surveys and an apparent increase in weight at length, evidence of stock renewal is lacking. Considering the historical decline in skate biomass, the lack of comparable data for recent years on current stock status (due to change in survey gear), the uncertainty about the stock's ability to rebuild in the absence of information on juvenile survival, and an unregulated fishery outside 200 nautical miles, an increase in harvest levels would not be prudent (Kulka and Mowbray 1998).

Spinytail and barndoor skates are primarily deep water species and have less extensive distributions than the thorny skate. These two species are found in fairly high concentrations along the shelf edge in the deep channels between the banks. After 1985, most of the concentrations of barndoor skate were found along the shelf break between 48°N and 50°N. Smooth skate, another species with a more limited distribution than thorny skate, appeared more common on the Southern Grand Bank during 1991 to 1994 (Kulka et al. 1996).

Thorny skate are distributed in the area of the White Rose field, but recently in relatively low density. Data from recent years (1995 to 1997) indicate a single concentration of thorny skate on the Southern Grand Bank that straddles the 3N and 3O, and the 3O and 3Ps divisional borders. This concentration has demonstrated seasonal and annual shifts over the three years. Distribution dynamics and earlier studies suggest that this concentration represents a single stock (Kulka and Mowbray 1998a).

The biomass proportions in the 1996 to 1997 spring survey were 22 percent in 3LN, 47 percent in 3O, and 31 percent in 3Ps (Kulka and Mowbray 1998a).

3.8.2.2 Wolffish

The commercial wolffish in Newfoundland are made up of two species: the Atlantic or striped wolffish and the spotted wolffish.

Habitat/Life History

The Atlantic (striped) wolffish is found in depths ranging from 100 to 350 m and in temperatures as low as 0.4°C. This species spawns inshore at depths of 5 to 15 m in August and September. The spotted wolffish lives in deeper waters (beyond 475 m) at temperatures of 3.1 to 4.0 °C. Spawning information for spotted wolffish is limited, although it is believed that they spawn in late autumn to early winter. There are suggestions that larvae of this species are initially pelagic (Kulka 1996a).

The Atlantic wolffish feeds on a variety of benthic invertebrates including echinoderms, molluscs and crustaceans. Redfish are also eaten by this species in certain regions. Juvenile wolffish have been found in cod stomachs (Scott and Scott 1988).

Spotted wolffish food consists primarily of hard-shelled benthic invertebrates such as crustaceans and molluscs. Other prey include seastars, tube worms, sea urchins, fish and seaweed. Spotted wolffish have been reported in the stomachs of cod, pollock and Greenland shark (*Somniosus microcephalus*) (Scott and Scott 1988).

Status

Wolffish are taken as by-catch in trawler fisheries around Newfoundland. The two wolffish species combined total the second most abundant by-catch in Canadian trawler catches after skates.

Annual research vessel surveys indicate that spotted wolffish are found primarily in the more northern areas off Newfoundland, they are relatively rare south of 3L. Survey data indicated a decline in this species in 3L during 1989 and 1990. Atlantic (striped) wolffish were most abundant in 3N, followed by 3O. There was a gradual decline in biomass of this species between 1986 and 1995 but it was not as dramatic as that of spotted wolffish. There is a persistent concentration of Atlantic wolffish in a small area of the Southern Grand Bank that straddles the boundary between 3N and 3O (Kulka 1996a; Kulka and DeBlois 1996).

The distribution for spotted wolffish biomass (1991 to 1994) indicates areas of low to medium concentration near White Rose, whereas only areas of low concentration of Atlantic wolffish (1991 to 1994) are proximate to White Rose (Kulka and DeBlois 1996).

3.8.2.3 Monkfish

Habitat/Life History

The monkfish or goosefish is a bottom dwelling sluggish fish that lives in relatively warm waters. It has been found in depths from the tideline to 650 m and in temperatures from 0 to 21°C. Limited studies have suggested seasonal migration in this species; shallow waters in the summer and deep waters in the winter (Kulka 1996b).

It is believed that this species spawns from June to September and that the larvae are planktonic for a period of time before settling to the bottom (Kulka 1996b).

This voracious predator will feed on anything digestible. Reported stomach contents include numerous fish species such as herring, sand lance, alewives, menhaden (*Brevoortia tyrannus*), smelt (*Osmerus mordax*), cod, haddock, mackerel, cunner, sculpins, sea ravens (*Hemitripterus americanus*), flounders and skates. They also eat invertebrates such as crabs, squid, other molluscs, seastars and polychaetes. Most of its feeding is conducted at the bottom, reflected by the predominant prey items. Adult monkfish have been found in swordfish, while juvenile monkfish have been reported in stomachs of other predacious fish (Scott and Scott 1988).

Status

Research surveys have indicated that most monkfish are in Divisions 3O and 3Ps. To date, the research vessel surveys have not found any monkfish in 3L and very few in 3N (Kulka 1996b).

3.8.2.4 White Hake

Habitat/Life History

Adult white hake occur over a wide range of depths (200 to 1,000 m) and are able to tolerate a wide temperature range (0 to 21°C). Their preferred temperature range is 5 to 11°C, which tends to restrict their distribution on the Grand Banks to a small part of the south and western edges in Division 3O. This species appears to spawn in mid-summer on the Grand Banks. Early stages remain pelagic and do not move to the bottom until they reach 8 to 13 cm in length (Kulka 1998b; Kulka and Mowbray 1998b).

Herring and other hake are the primary prey of adult white hake. Other important prey include Atlantic mackerel and northern shrimp. The diet of juvenile white hake is dominated by zooplankton and benthic fauna. Cannibalism has been reported for this species. Other predators of white hake include cod and seals.

Status

Research vessel survey biomass indices indicate that white hake are found mostly in 3O and 3Ps. In spring, summer and fall surveys, white hake were distributed almost exclusively along the southwestern edge of the Grand Banks and the Laurentian Channel (Kulka 1998b).

Concurrent with declining biomass of this species was a decrease in mean length and weight of the hake. Spring and fall research vessel surveys, 1996 to 1998, indicated further hake concentrations along the southwest shelf of Southern Grand Bank (3O) and the shelf of St. Pierre Bank (3Ps) (Kulka and Mowbray 1998b). This distribution is similar to that reported for 1991 to 1994 (Kulka and DeBlois 1996). White hake have not been reported in the vicinity of White Rose.

3.8.2.5 Winter Flounder (Blackback Flounder)

Habitat/Life History

In the western North Atlantic, winter flounder are abundant and inhabit muddy to moderately hard bottoms. Throughout its range, it is known to migrate seasonally, moving away from the coast during winter. Around the coast of Newfoundland, at any time of the year, it is generally found in depths less than 40 m. To reside in this shallow habitat, it must be capable of adapting to wide temperature ranges, even sub-zero conditions (Kulka 1996c; Kulka and DeBlois 1996).

Winter flounder spawn in late winter and early spring. Released eggs adhere to substrate features (that is, rocks, vegetation), but upon hatching the larvae spend several months as plankton. After development, the young flounder return to the bottom (Kulka 1996c; Kulka and DeBlois 1996).

Winter flounder are primarily daytime bottom feeders. Prey include polychaetes, bivalves, gastropods and crustaceans. In the spring, planktonic crustaceans are more common to the diet. Seals, monkfish, dogfish and sea raven are consistent predators of winter flounder (Scott and Scott 1988).

Status

This species has traditionally been caught locally around the coast of Newfoundland in 3K, 3L and 3Ps to be used as lobster bait. Due to its habitation in relatively shallow areas, the winter flounder is seldom taken in RV survey trawls and, therefore, no estimates of biomass are available. Even morphometric data were not collected on this species until 1996 (Kulka 1996c; Kulka and DeBlois 1996).

3.8.3 Other Species Considered in the Terra Nova Environmental Impact Statement

Other invertebrate and finfish species considered in the Terra Nova EIS (Petro-Canada 1995: Section 4.8.16) include pollock, lumpfish (*Cyclopterus lumpus*) and sand lance.

There is not any new information to add to that presented in the Terra Nova EIS for each of the above species.

3.9 MARINE BIRDS

The Grand Banks and the southeastern coast of Newfoundland are very important areas for over 60 species of sea-associated birds (Table 3.9-1). Of these 60 species, approximately 18 are pelagic, nine of which nest in the study area. There are several million of these nesting birds, and there are millions of annual visitors that forage on the Grand Banks. In addition, a wide variety of coastal species, including gulls, terns, cormorants, waterfowl and shorebirds frequent the shore zones of the study area.

The bird community within the study area was described in the Hibernia EIS in 1985 (Mobil 1985) and updated in 1995 for the Terra Nova EIS (Petro-Canada 1995). The occurrence, distribution, reproductive characteristics and foraging habits of the seabirds in and around the study area are outlined in Tables 3.9-1 to 3.9-6 (reproduced from the two previous EISs). Several recent studies (since 1995) have provided additional information on seabirds in the study area. In particular, a number of studies have begun to address the potential effects on seabirds of the closure of the eastern Canadian ground-fishery and anomalous cold surface-water events in the early 1990s that have delayed the arrival of capelin to inshore waters off Newfoundland.

Table 3.9–1 Sea-Associated Birds Recorded in the Study Area (from Mobil 1985)

Common Name	Scientific Name	Distribution in Study Area	Common Name	Scientific Name	Distribution in Study Area
Red-throated loon [?]	*Gavia stellata*	coastal	American golden-plover	*Pluvialis dominica*	littoral
Common loon [?]	*Gavia immer*	coastal	Semipalmated plover	*Charadrius semipalmatus*	littoral
Pied-billed grebe	*Podilymbus podiceps*	coastal	Greater yellowlegs	*Tringa melanoleuca*	littoral
Red-necked grebe	*Podiceps grisegena*	coastal	Spotted sandpiper [1]	*Actitis macularia*	littoral
Northern fulmar [1]	*Fulmarus glacialis*	offshore, coastal	Semipalmated sandpiper	*Calidris pusilla*	littoral
Cory's shearwater	*Colonectris diomedea*	offshore	White-rumped sandpiper	*Calidris fuscicollis*	littoral
Greater shearwater	*Puffinus gravis*	offshore, nearshore	Purple sandpiper	*Calidris maritima*	littoral
Sooty shearwater	*Puffinus griseus*	offshore, nearshore	Red-necked phalarope	*Phalaropus lobatus*	offshore
Manx shearwater [1]	*Puffinus puffinus*	offshore, nearshore	Red phalarope	*Phalaropus fulicaria*	offshore
Little shearwater	*Puffinus assimilis*	offshore	Pomarine jaeger	*Stercorarius pomarinus*	offshore
Wilson's storm-petrel	*Oceanites oceanicus*	offshore	Parasitic jaeger	*Stercorarius parasiticus*	offshore
Leach's storm-petrel [1]	*Oceanodroma leucorhoa*	offshore	Long-tailed jaeger	*Stercorarius longicaudus*	offshore
Northern gannet [1]	*Sula bassanus*	offshore, coastal	Great skua	*Catharacta skua*	offshore
Great cormorant [?]	*Phalacrocorax carbo*	coastal	Common black-headed gull	*Larus ridibundus*	coastal
Double-crested cormorant [1]	*Phalacrocorax auritus*	coastal	Ring-billed gull	*Larus delawarensis*	coastal
Canada goose [?]	*Branta canadensis*	coastal	Herring gull [1]	*Larus argentatus*	coastal, offshore
American black duck [?]	*Anas rubripes*	coastal	Iceland gull	*Larus glaucoides*	coastal, offshore
Ring-necked duck	*Aythya collaris*	coastal	Lesser black-backed gull	*Larus fuscus*	coastal, offshore
Greater scaup	*Aythya marila*	coastal	Glaucous gull	*Larus hyperboreus*	coastal, offshore
Common eider [?]	*Somateria mollissima*	coastal	Great black-backed gull [1]	*Larus marinus*	coastal, offshore
King eider	*Somateria spectabilis*	coastal	Black-legged kittiwake [1]	*Rissa tridactyla*	coastal, offshore
Harlequin duck	*Histrionicus histrionicus*	coastal	Sabine's gull	*Xema sabini*	offshore
Oldsquaw	*Clangula hyemalis*	coastal	Ivory gull	*Pagophila eburnea*	offshore
Black scoter	*Melanitta nigra*	coastal	Common tern [1]	*Sterna hirundo*	coastal, offshore
Surf scoter	*Melanitta perspicillata*	coastal	Arctic tern [1]	*Sterna paradisaea*	coastal, offshore
White-winged scoter	*Melanitta fusca*	coastal	Dovekie	*Alle alle*	offshore, coastal
Common goldeneye	*Bucephala clangula*	coastal	Common murre [1]	*Uria aalge*	coastal, offshore
Bufflehead	*Bucephala albeola*	coastal	Thick-billed murre [1]	*Uria lomvia*	coastal, offshore
Common merganser	*Mergus merganser*	coastal	Razorbill [1]	*Alca torda*	coastal, offshore
Red-breasted merganser	*Mergus serrator*	coastal	Black guillemot [1]	*Cepphus grylle*	coastal
Black-bellied plover	*Pluvialis squatarola*	littoral	Atlantic puffin [1]	*Fratercula arctica*	coastal, offshore

[1] Indicates species that nest along the coast of the study area. [?] Indicates species that may nest along the coast of the study area.

Table 3.9–2 Reproduction Parameters of Seabirds Nesting in the Study Area

Species	Mean Adult Survival Rate	Age of First Breeding (yr)	Clutch Size	Breeding Success [1]	Sources
Northern fulmar	0.97	6-12	1	0.55	Dunnet et al. (1963); Dunnet and Ollason (1978)
Leach's storm-petrel	> 0.70	3-5	1	0.79-0.94	Huntington (1963); Wilbur (1969); Morse and Buchheister (1977)
Manx shearwater	0.90	5-6	1	0.69	Perrins et al. (1973)
Northern gannet	0.95	4-7	1	0.81	Nelson (1966); Montevecchi and Porter (1980)
Herring gull	0.80-0.85	3-7	2-3	1.03-1.58	Haycock and Threlfall (1975); Kadlec (1976); Pierotti (1982)
Great black-backed gull	-	4-5	3	0.50-2.11	Butler and Trivelpiece (1981)
Black-legged kittiwake	0.81-0.86	3-7	2	0.54-0.58	Maunder and Threlfall (1972); Wooler and Coulson (1977)
Common and arctic terns	0.86	2-4	1-3	0.59-0.77	Cullen (1956); Kirkham (1984)
Common murre	0.92	4-5	1	0.72	Birkhead and Hudson (1977)
Thick-billed murre	0.91	3-5	1	0.68 0.76	Birkhead and Hudson (1977); Gaston and Nettleship (1981)
Razorbill	0.89-0.92	4-6	1	0.55-0.71	Bedard (1969); Lloyd and Perrins (1977); Hudson (1982)
Black guillemot	0.77-0.89	2	1-2	0.12-0.78	Asbirk (1979); Cairns (1981)
Atlantic puffin	0.95	4-6	1	0.60-0.66 0.42	Ashcroft (1979); Harris (1983); Rodway et al. (1998)

Source: From Mobil 1985 with updates

[1] Numbers of chicks fledged per breeding pair of adults.

Table 3.9–3 Summary of Seabird Nesting, Hatching and Fledging in the Study Area

Species	Egg Laying	Incubation	Hatching	Nesting	Fledging	Comments
Northern fulmar	2nd half May[1]	47-51 days[2]	observed July 10[1]	47-51 days[2]	late Aug-early Sept[2]	Canadian breeding population is 360,000 pairs[3]; NF colony may represent new colonization[2].
Manx shearwater	-	-	-	-	-	Information on breeding activity in coastal NF is lacking. One colony has been identified on Middle Lawn Island[4].
Leach's storm-petrel	mid May to mid August [5,6,7] peak: first half of June	41-42 days [5,6,7]	peak: last half of July[5,6,7]	63-70	until mid Nov. peak: late Sept.	Baccalieu colony is probably largest in the world. [8,9]
Northern gannet	mid to late May[10,11]	42 days [10,11]	late June to early July	91 days[10,11]	late Sept. to early Oct.[9,10]	NF breeding population represents 17% of the eastern Canadian population. NF's population is stable and increasing
Herring gull; Great black-backed gull	mid to late May[12,13,14]	26-29 days [12,13,14]	mid-late June	45 days[12] 50-55 days [12,14]	late July - early August	Nest singly or in colonies at many locations along NF East Coast[15]. Study area breeding population is only a small proportion of total Canadian[3] population.
Black-legged kittiwake	late May-early June[17]	27 days[17]	late June[17]	42 days[17]	early Aug. [17]	Three major colonies along Avalon Peninsula[16]. NF group represents approx. 33% total Canadian breeding population.
Common tern; Arctic tern	first half June[18]	22 days [18]	mid July	21-26 days[18]	late July-early Aug. [18]	Occur singly or in small colonies along the Avalon Peninsula[16]
Common murre	mid May[19, 20]	32 days[19,20]		23 days[19,20]	mid-late July	Breeding population in study areas represents 17% total Canadian breeding population[3].
Thick-billed murre	early June[19,20]				late July-early August	Nesting population in study area represents < 1% of Canadian breeding population[21]
Razorbill	early June	34-39 days	early-mid July	24 days	late July - early August	Nesting population in study area represents 3% of the North American population[3]. Information extrapolated from data for Labrador [20].
Atlantic puffin	mid-late May[22]	42 days[22]	early July[22]	40-45 days[22]	mid to late August[22]	Most abundant alcid in study area[3]. Includes approx. 72% of the N. American population[3].
Black guillemot	mid May - early June[22]	28-33 days[22]	mid June - mid July[22]	34-39 days[22]	early - late August[22]	No estimate of the number of breeding birds in the study area, but considered to be low[3,24].

Source: Mobil 1985

(1) Montevecchi et al. (1978)
(2) Cramp and Simmons (1977)
(3) Nettleship (1980)
(4) Lien and Grimmer (1978)
(5) Grimmer (1980)
(6) Huntington (1963)
(7) Wilbur (1969)
(8) Maccarone and Montevecchi (1981)
(9) Pitocchelli et al. (1981)
(10) Kirkham (1980)
(11) Montevecchi and Porter (1980)
(12) Haycock and Threlfall (1975)
(13) Pierotti (1982)
(14) Butler and Trivelpiece (1981)
(15) Erwin (1971)
(16) Brown et al. (1975)
(17) Maunder and Threlfall (1972)
(18) Hawksley (1950)
(19) Tuck (1961)
(20) Birkhead and Nettleship (1982)
(21) Gaston (1980)
(22) Cairns (1981)
(23) Renaud and Bradsteet (1980)
(24) Nettleship (1972)

Table 3.9–4 Estimates of the Numbers of Nesting Seabirds Within the Study Area and at Major Colonies in or Near the Study Area

Species	Study Area		Major Colonies							
	Nesting Population		In the Study Area					Near the Study Area		
	No. Nesting Sites	No. Nesting Pairs	WBI	CSM	IRON	CORBIN	MLI	BI	GREEN	GC
Leach's storm-petrel	8	1,006,682	870,020 [a]		10,000	100,000	26,313	3,336,000	72,000	100,000
Atlantic puffin	6	216,175	216,000 [a]					30,000		400
Common murre	7	87,544	77,487	10,000				4,000		
Black-legged kittiwake	25	60,263 +	43,927 [a]	10,000		50		12,975		200
Herring gull	77	30,175 +	6,995	x	600	5,000	20	x	1	113
Northern gannet	1	5,485		5,485				677		
Ring-billed gull	6	1,839								
Great black-backed gull	51	1,692 +	203 [a]	x	50	25	6	x		5
Thick-billed murre	2	1,600	600	1,000				181		
Razorbill	7	592	330	100				100		?
Black guillemot	22	467 +	20 +		x	x	8	100	?	
Manx shearwater	1	100	?				100			
Double-crested cormorant	3	40								
Great cormorant	2	20								
Northern Fulmar [b]	1?	21 +?	21	?				?	?	?
Common and Arctic tern	51	2,812 +								
Total Sites	149									
Total Nesting Pairs			>1,215,603	>26,585	>10,650	>105,075	26,447	>3,384,033	72,001	100,718

Source: Petro-Canada (1995). Most data from Cairns et al. (1989) except for [a] and [b].
[a] Data for Great Island (1 of the 3 main islands that comprise the Witless Bay Islands) from Rodway et al. (1996).
[b] Data from Stenhouse and Montevecchi (1999). Only the number of confirmed breeding pairs are presented

Notes:

1. Major colony names are:
   - WBI = Witless Bay Islands
   - CSM = Cape St. Mary's
   - IRON = Iron Island
   - BI = Baccalieu Island
   - GREEN = Green Island
   - GC = St. Pierre Grand Columbier
   - MLI = Middle Lawn Island
   - CORBIN = Corbin Island
2. Symbols are:
   - x = present but number nesting unknown
   - ? = possibly nesting

Table 3.9–5 Foraging Strategy and Prey of Sea-Associated Birds that Occur in the Study Area

Species (Species-group)	Foraging Strategy	Prey	Source
Seabirds			
Northern fulmar	Surface feeding	Fish, cephalopods, crustaceans, offal	Brown (1970)
Greater shearwater	Pursuit plunging	Capelin, squid, crustaceans, offal	Brown et al. (1981)
Sooty shearwater	Pursuit plunging	Capelin, squid, crustaceans, offal	Brown et al. (1981)
Storm-petrels	Surface feeding	Myctophid fish, amphipods	Linton (1978)
Northern gannet	Deep plunging	Mackerel, capelin, squid	Kirkham (1980)
Phalaropes	Surface feeding	Copepods	Brown (1980)
Jaegers and skuas	Kleptoparasitism	Fish	Hoffman et al. (1981)
Herring gull [1]	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Iceland gull	Surface feeding	Fish, crustaceans, cephalopods, offal	Cramp and Simmons (1977)
Glaucous gull	Surface feeding	Fish, crustaceans, cephalopods, offal	Cramp and Simmons (1977)
Great black-backed gull [1]	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Black-legged kittiwake	Surface feeding	Fish, crustaceans, cephalopods, offal	Threlfall (1968)
Terns	Surface and pursuit plunging	Fish, crustaceans	Braune and Gaskin (1982)
Alcids			
Dovekie	Pursuit diving	Amphipods, copepods	Bradstreet (1982)
Common murre	Pursuit diving	Fish, invertebrates	Bradstreet (1983)
Thick-billed murre	Pursuit diving	Fish, invertebrates	Tuck (1961)
Black guillemot	Pursuit diving	Fish, invertebrates	Cairns (1981)
Razorbill	Pursuit diving	Fish, invertebrates	Bradstreet (1983)
Atlantic puffin	Pursuit diving	Fish, invertebrates	Bradstreet (1983)
Waterfowl (eiders)	Bottom feeding	Molluscs, crustaceans	Cantin et al. (1974)
Loons	Surface diving	Fish, molluscs, crustaceans	Cramp and Simmons (1977)
Cormorants	Surface diving	Fish	Palmer (1962)
Shorebirds	Intertidal probing	Invertebrates	Palmer (1967)

[1] These species feed on seabird eggs and chicks and occasionally adults (Rodway et al. 1996; Stenhouse and Montevecchi 1999).

Source: from Mobil 1985 with updates

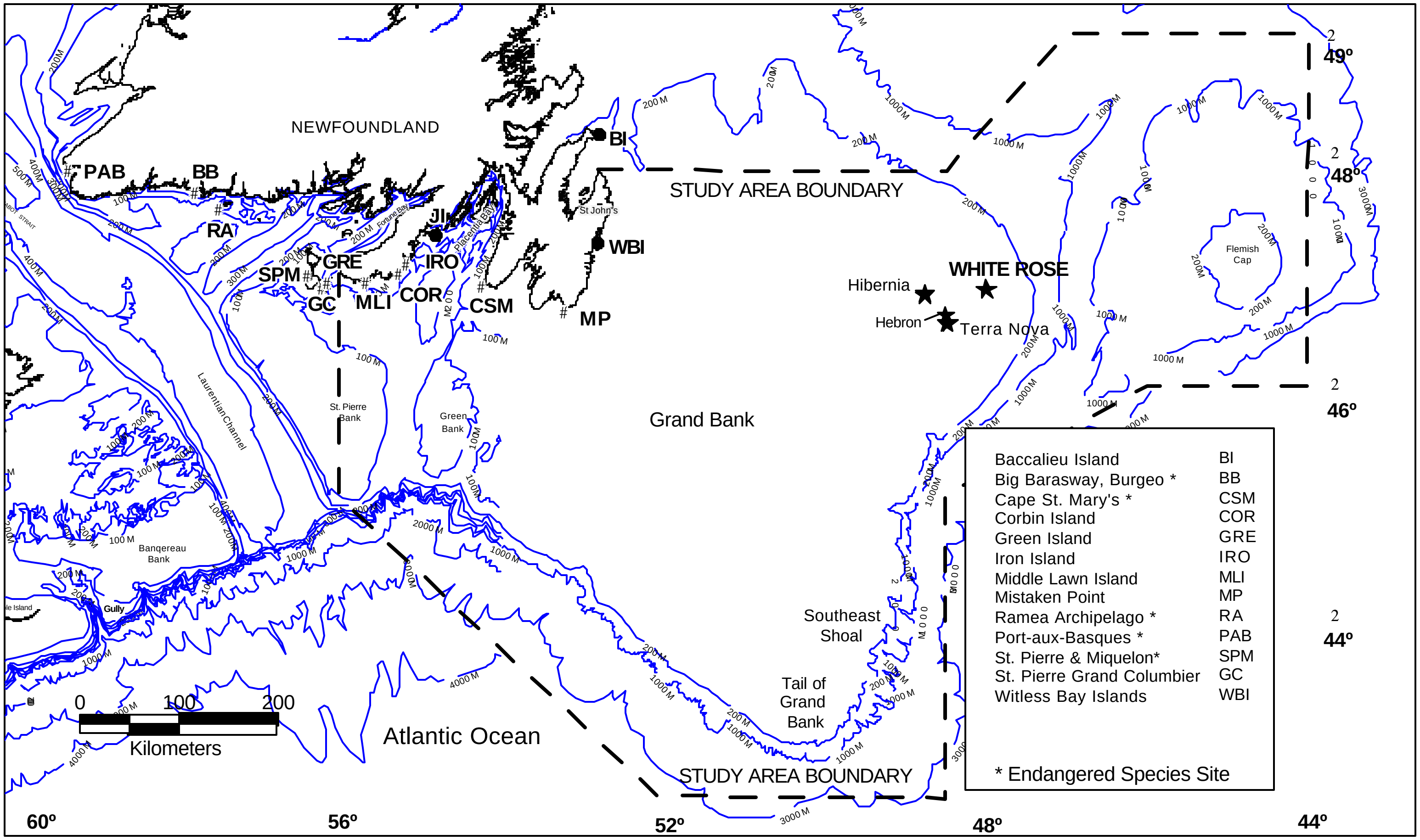
Table 3.9–6 Summary of Bird Distributions in the Study Area

Area	Subarea	Birds Commonly Observed
Flemish Cap		Northern fulmar, shearwaters, black-legged kittiwake, storm-petrels and dovekie.
Coastal waters of Newfoundland		Summer: Large numbers of northern gannet, herring gull, black-legged kittiwake, common murre and Atlantic puffin. Small numbers of northern fulmar, great black-backed gull, terns, thick-billed murre, razorbill and black guillemot. Large numbers of Leach's storm-petrel are present, but rarely observed.
		Winter: Large numbers of ducks (primarily common eiders), shorebirds, gulls, murres and dovekie.
Grand Banks	Southeast Shoal	Summer: Northern fulmar, greater shearwater, sooty shearwater, storm-petrels, jaegers and skuas.
		Winter: Northern fulmar and black-legged kittiwake.
	"Tail of the Bank"	Spring and Summer: Northern fulmar and shearwaters common; storm-petrels, jaegers, black-legged kittiwake and murres also present.
		Winter: Large numbers of black-legged kittiwake, murres and dovekie.
	Shelf Edge	Spring and Summer: Northern fulmar, shearwaters, storm-petrels, jaegers and black-legged kittiwake common; phalaropes also present.
		Winter: Large numbers of northern fulmar, black-legged kittiwake, glaucous gull, Iceland gull, skuas and dovekie.
Source: from Mobil 1985		

3.9.1 Breeding Biology and Nesting Populations

Most seabirds nesting in the study area have high survival rates, low fecundity and deferred maturity. The available information on various aspects of the reproductive biology of the species nesting in the study area is summarized in Tables 3.9-2 and 3.9-3. Census data for the study area (primarily from Cairns et al. 1989) and for the major colonies in and near the study area, are presented in Table 3.9-4. The locations of these major colonies, along with other important sites, are shown in Figure 3.9-1. Surveys conducted in 1992 to 1994 for several species of seabirds breeding on Great Island in Witless Bay (Rodway et al. 1996) and new survey data for Northern fulmars (*Fulmarus glacialis*) in Atlantic Canada (Stenhouse and Montevecchi 1999b) provide the only substantive updates to the Terra Nova EIS on nesting population size.

Figure 3.9–1 Location of Important Seabird Sites Within and Near the White Rose Study Area



The number of breeding pairs of Atlantic puffins (*Fratercula arctica*) on Great Island was estimated at 123,000 in 1993-94 (Rodway et al. 1996). This represents 33 percent of the North American Atlantic puffin population and more than doubles the previous estimate from 1979 (Cairns et al. 1989), which Rodway et al. (1996) attribute to sampling earlier in the breeding season, during incubation, when the confounding effects of breeding success are avoided. When the Great Island estimate is combined with previous estimates for Green Island (22,000) and Gull Island (71,000), 216,000 breeding pairs of puffins occur in the Witless Bay Ecological Reserve. This represents 57 percent of the North American Atlantic puffin population. It appears that the number of Atlantic puffins on Great Island (and probably off Newfoundland in general) is increasing, as puffins expand to inland areas of the Witless Bay island (Rodway et al. 1996). Gull predation has not reduced the breeding success of puffins; a fledging rate of 0.42 chicks per burrow was observed in 1992-93 (Rodway et al. 1998).

Rodway et al. (1996) also censured other seabird species breeding on Great Island in 1993-94. They estimated that there were 23,787 pairs of black-legged kittiwakes (*Rissa tridactyla*) breeding on this island and suggest that there has been little change since the previous survey conducted in 1968. Approximately 340,000 pairs of Leach's storm-petrels (*Oceanodroma leucorhoa*) and 40 pairs of great black-backed gulls (*Larus marinus*) were estimated to breed on Great Island.

The breeding population of Northern fulmars in Atlantic Canada has increased steadily over the last 25 years (Stenhouse and Montevecchi 1999b). Site-holding pairs have been observed within the study area at islands in Witless Bay, and also at Cape St. Mary's and near the study area at Baccalieu Island, Green Island and St. Pierre. However, breeding has only been confirmed at Great (18 chicks), Gull (one chick, two eggs) and Ship islands (one chick) (Stenhouse and Montevecchi 1999b).

3.9.2 Prey and Foraging Habits

Sea-associated birds in the study area eat a variety of prey including capelin, copepods, amphipods and short-finned squid. Different species specialize in foraging at the surface, at shallow depths and by diving to deep depths. The main prey and foraging strategies of seabirds in the study area are summarized in Table 3.9-5.

Studies suggest that the foraging strategy of seabirds is related to its breeding success during periods of limited food availability (Bryant et al. 1999; Regehr and Rodway 1999). Recent reductions in food availability in the study area occurred when the inshore spawning migration of capelin, a major prey for many seabird species, was delayed by one month in 1992 and 1993 in the northwest Atlantic, and the ground fisheries moratorium eliminated the production of fish offal, an important alternative food source for *Larus* gulls and black-legged kittiwakes (Regehr and Rodway 1999). Inshore surface feeders including black-legged kittiwakes, herring and great black-backed gulls, had lower hatching, fledging and breeding success than in previous years. Pursuit divers, including the Atlantic puffin and common murre (*Uria aalge*), had similar reproductive success as in previous years when capelin arrival was “on time” while offshore surface feeders like the Leach's storm-petrel had high breeding success (Regehr and Rodway 1999). Inshore surface feeders may be particularly sensitive to changes in prey availability because their foraging strategy makes them more vulnerable to oceanographic changes in temperature, depth of the thermocline, and upwelling and less able to exploit alternative prey species (Regehr and Rodway 1999).

Similarly, the breeding success of common and thick-billed murres (*Uria lomuia*) in the Gannet Islands, Labrador, was unchanged despite the reduced availability of capelin. These pursuit divers fed their chicks primarily shanny in the mid-1990s versus capelin in the early 1980s (Bryant et al. 1999).

Gull predation on seabird adults, chicks and eggs has increased in recent years and probably varies with the availability of inshore spawning capelin (Rodway et al. 1996; Stenhouse and Montevecchi 1999a). Montevecchi and Myers (1997) noted a shift in the diet of northern gannets (*Sula bassanus*) off the northeast coast of Newfoundland that was related to changes in sea surface temperature on the Newfoundland Shelf. They observed a shift in the 1990s from a diet that consisted of predominantly migratory warm-water pelagic fish (for example, mackerel) and squid, to one of mostly regional cold-water pelagic fish (for example, capelin).

3.9.3 Geographic and Seasonal Distribution

The distributional data presented in the Hibernia EIS (Mobil 1985) and summarized in Table 3.9-6 generally remain unchanged. Seasonal and annual variation in seabird distribution within the study area are still poorly known. Observation programs at both the Hibernia and Terra Nova sites provide additional information on the occurrence of seabirds in the study area. Also, an offshore bird survey conducted for Husky Oil from supply vessels travelling between St. John’s and the White Rose site provides a limited amount of useful data (Wiese and Montevecchi 1999). These three surveys are discussed below in further detail.

Periodic seabird sightings were made at the Hibernia site from November 1997 to August 1998. The data collected from this site are not presented in detail here because there were only 23 observation periods and these data had unknown observer effort (that is, duration of observation period). However, the data agree with previous seasonal occurrence observations of seabirds on the Grand Banks; large numbers of dovekies (*Alle alle*) were sighted in winter and shearwaters and storm-petrels were sighted in summer.

The seabird monitoring program employed at the Terra Nova site was more structured than the monitoring at Hibernia, and therefore, produced better sighting data. Data were collected from May to September 1999 aboard dredging vessels. Vessel personnel were trained to identify seabirds and collect various types of data (species, number of birds, behaviour) by an experienced seabird biologist prior to conducting observations. A trained crew member usually conducted three 20-min watches per day (weather permitting). The data (Table 3.9-7) provide information on time of occurrence and relative species abundance near the Terra Nova site, as well as providing information on standardized observations per effort. As expected, large numbers of shearwaters (mostly greaters (*Puffinus gravis*)) were sighted, beginning in June; over 67 percent of seabirds sighted were shearwaters. Gulls (*Larus* spp.) were first sighted in July and accounted for 16.5 percent of the sightings. Smaller numbers of black-legged kittiwakes (10.8 percent) were sighted mostly in June. Storm-petrels, fulmars, and skuas (*Catharacta skua*) were also sighted, along with a few alcids (Table 3.9-7).

Seabird data collected from offshore supply vessels travelling to and from the White Rose area during August and September 1999 (Wiese and Montevecchi 1999) have the potential to provide updated information on seabird distribution within the study area. The basic count data from these surveys reveal that approximately 73 percent of all seabirds sighted were greater shearwaters. Leach's storm-petrels, Atlantic puffins, and northern fulmars comprised most of the remaining sightings (Appendix 4 from Wiese and Montevecchi 1999).

3.9.4 Important Areas, Times and Species

The southeastern coast of Newfoundland and the Grand Banks are very important areas for many species of sea-associated birds. Critical areas, times of year and species are outlined below. Most of this information was obtained from Lock et al. (1994).

Table 3.9–7 Sea-associated Birds Sighted from Dredging Vessels at the Terra Nova Site from May to September 1999

Species	May	June	July	August	September	Total	% of Total
Northern Fulmar		25	14	33	6	78	1.6
Greater Shearwater	16	444	589	379	200	1,628	33.8
Manx Shearwater				1		1	0.0
Shearwater spp.	4	4	402	832	364	1,606	33.4
Storm-petrel spp.		1	112	17	24	154	3.2
Northern Gannet				2	1	3	0.1
Unknown Duck				2		2	0.0
Gulls			26	65	701	792	16.5
Black-legged Kittiwake	39	439	14	4	26	522	10.8
Great Skua			8	2	3	13	0.3
Dovekie			1	4		5	0.1
Common Murre		4				4	0.1
Murre spp.	2		1			3	0.1
Albatros	1					1	0.0
Total	**62**	**917**	**1,167**	**1,341**	**1,325**	**4,812**	**100.0**
Total Observation Time (min)	1,035	1,535	1,823	1,285	920	6,598	

Data from U. Williams (Petro-Canada). Unidentified seabirds are not included

3.9.4.1 Major Nesting Colonies

Some of the largest seabird nesting colonies in eastern North America south of Hudson Strait are located along the coastline of the Avalon and Burin peninsulas. Almost 3.5 million pairs of Leach's storm-petrels nest on Baccalieu Island, just north of the study area and approximately 900,00 pairs nest on the Witless Bay islands. This includes the majority of the entire Atlantic Ocean population of this species. The Witless Bay islands are also important breeding areas for Atlantic puffins (216,000 pairs), common murres (approximately 77,000 pairs) and black-legged kittiwakes (approximately 43,000 pairs). The Cape St. Mary's area is one of only six nesting sites of northern gannets in North America. Large numbers of common murres and black-legged kittiwakes also nest there. Other islands along the Burin Peninsula are also important breeding areas for large numbers of Leach's storm-petrels.

3.9.4.2 Summer Concentrations

Most of the world population of greater shearwaters, estimated at five million birds, smaller numbers of sooty shearwaters (*Puffinus griseus*) and large numbers of Wilson's storm-petrels (*Oceanites oceanicus*), spend the summer on the Grand Banks, wintering from their nesting grounds in the south Atlantic Ocean (Lock et al. 1994). Most of these birds concentrate on the Southeast Shoal of the Grand Banks, where they moult and forage.

3.9.4.3 Winter Concentrations

Almost four million thick-billed murres winter on the Grand Banks, over half of the five to six million that breed in western Greenland and the eastern Canadian Arctic. The Grand Banks is also the chief wintering area for the approximately 14 million dovekies that nest along northwest Greenland. Thousands of waterfowl concentrate near the Cape St. Mary's area, with substantial concentrations also near Argentia and Jude Island, Placentia Bay and Mistaken Point area (southeastern Avalon Peninsula). However, the locations of these winter concentration areas vary within a season and from year to year (Lock et al. 1994). The Mistaken Point area has been designated as an Important Bird Area by BirdLife International and as a Provincial Ecological Reserve because waterfowl winter there and approximately 150 to 225 purple sandpipers (*Calidris maritma*) overwinter at the site (*www.bsc-eoc.org/Iba*).

3.9.4.4 Rare Species

Several endangered or threatened bird species occur in the inshore area. The population of harlequin ducks (*Histrionicus histrionicus*) in eastern North America is extremely small and apparently in decline (Vickery 1988; Goudie 1989). In Canada, it is classified as an endangered species by the Committee on the Status of

Endangered Wildlife in Canada (COSEWIC; Goudie 1990) and in 1996 the eastern Canadian population was estimated at 1,500 individuals (Twolan and Nadeau 1998). The Cape St. Mary's area (145 individuals in 1980-81) and Ramea archipelago (20-30 individuals) in southern Newfoundland are important local wintering staging areas for the harlequin duck (Lock et al. 1994; Vickery 1988). The Christmas count data collected at Cape St. Mary’s in December 1999 indicated that 106 harlequin ducks were present. On 23 March 2000, 80 harlequin ducks were counted at Cape St. Mary’s (P. Ryan, pers. comm.).

Several pairs of piping plovers (*Charadrius melodus*), an endangered species (COSEWIC 1999), nest near the study area. The population estimate for eastern Canada in 1996 was 426 adult birds (Twolan and Nadeau 1998). Eight pairs of piping plovers were reported west of the study area at the Big Barasway in Burgeo and near Port-aux-Basques, Newfoundland (Morrison et al. 1995) while four pairs were reported at two sites in Miquelon (Lock et al. 1994).

The Canadian population of the ivory gull (*Pagophila eburnea*) is classified as vulnerable by COSEWIC (Alvo and MacDonald 1996). This species is generally associated with offshore pack ice that occurs commonly in winter off Newfoundland and occasionally off Atlantic Nova Scotia (Tufts 1986). Manx shearwaters (*Puffinus puffinus*) and common black-headed gulls (*Larus ridibundus*) have small nesting populations in southern and eastern Newfoundland, but are primarily European species.

3.10 MARINE MAMMALS – EXISTING CONDITIONS

Eighteen species of marine mammal are known to occur in the study area, including 14 species of whales and dolphins (cetaceans) and four species of seals (phocids). A few additional species may occur, but because of their rarity in the area are not considered important components of the ecosystem. Although most species are seasonal inhabitants, the waters of the Grand Banks and surrounding areas are important feeding grounds for some. The species composition, COSEWIC status, seasonal occurrence, estimated population sizes and prey of the marine mammal community are outlined in Tables 3.10-1 to 3.10-3.

The marine mammal community within the study area was described in the Hibernia EIS in 1985 (Mobil 1985) and updated in 1995 for the Terra Nova EIS (Petro-Canada 1996). Most of the description on distribution in these reports was based on marine mammal surveys conducted for the Hibernia EIS (Parsons and Brownlie 1981). Although nearly 20 years have elapsed, the Parsons and Brownlie surveys remain the most comprehensive data available on the spatial and temporal occurrence of marine mammals in the study area. The information from these surveys and other biological information presented in both EISs are not repeated in this report and the reader is referred to Mobil (1985) and Petro-Canada (1995).

Table 3.10–1 Marine Mammals in the Study Area

Species	COSEWIC Status [1]	Occurrence in Study Area	Source of Updated Information
Mysticetes (Baleen Whales)			
North Atlantic Right Whale (*Eubalaena glacialis*)	E	unknown	
Humpback Whale (*Megaptera novaeangliae*)	V	transient and summer resident	
Blue Whale (*Balaenoptera musculus*)	V	late winter, spring, and summer visitor	
Fin Whale (*Balaenoptera physalus*)	V	transient and summer resident	
Sei Whale (*Balaenoptera borealis*)	NC	late summer visitor	
Minke Whale (*Balaenoptera acutorostrata*)	NC	transient and summer resident	
Odontocetes (Toothed Whales)			
Sperm Whale (*Physeter macrocephalus*)	NAR	transient and summer resident	
Northern Bottlenose Whale (*Hyperoodon ampullatus*)	V[2]	transient	
Killer Whale (*Orcinus orca*)	I	year-round resident	Lien et al. (1988)
Long-finned Pilot Whale (*Globicephala melas*)	NAR	permanent resident	
Common Dolphin (*Delphinus delphis*)	NAR	summer resident	
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)	NAR	summer resident	
White-beaked Dolphin (*Lagenorhynchus albirostris*)	NAR	transient and summer resident	
Harbour Porpoise (*Phocoena phocoena*)	T	summer resident	
Phocids (True Seals)			
Harbour Seal (*Phoca vitulina*)	I	permanent resident	
Grey Seal (*Halichoerus grypus*)	NAR	year-round resident	Stenson (1994)[3]
Harp Seal (*Phoca groenlandica*)	NC	winter visitor	Stenson and Kavanagh (1994) Stenson and Sjare (1997)
Hooded Seal (*Cystophora cristata*)	NAR	winter visitor	Stenson and Kavanagh (1994) G.B. Stenson (unplub. data)

[1] COSEWIC 1999
[2] Scotian Shelf (Gully) population
[3] Population numbers for hooded seals refer to Front and Gulf herds only
E = Endangered I = Indeterminate
T = Threatened NAR = Not at Risk
V = Vulnerable NC = Not Considered

Source: (Mobil 1985; With Updates Where Indicated)

Table 3.10–2 Population Estimates of Marine Mammals that Occur in the White Rose Study Area

	NW Atlantic Population Size	Population Occurring in the Study Area		
Species	**Estimated Number**	**Stock**	**Estimated Number**	**Source of Updated Information**
Mysticetes				
North Atlantic Right Whale	295	NW Atlantic	unknown	Knowlton et al. (1994)
Humpback Whale	5,505	NF/Labrador	1,700-3,200	Katona and Beard (1990);Whitehead (1982)
Blue Whale	308 [a]	NW Atlantic	unknown	Waring et al. (1999)
Fin Whale	2200 [b]	Cdn. E. Coast	unknown	Waring et al. (1999)
Sei Whale	Unknown	Nova Scotia	unknown	Waring et al. (1999)
Minke Whale	2790 [b]	Cdn. E. Coast	unknown	Waring et al. (1999)
Odontocetes				
Sperm Whale	unknown	North Atlantic	unknown	Reeves and Whitehead (1997)
Northern Bottlenose Whale	tens of thousands?	North Atlantic	unknown	Reeves et al. (1993)
Killer Whale	?		unknown	Lien et al. (1988)
Long-finned Pilot Whale	4,000-12,000	NW Atlantic	abundant	Nelson and Lien (1996)
Common Dolphin	22,215	NW Atlantic	unknown	Waring et al. (1999)
Atlantic White-sided Dolphin	27,200	NW Atlantic	unknown	Palka et al. (1997)
White-beaked Dolphin	unknown	NW Atlantic	unknown	Waring et al. (1999)
Harbour Porpoise	unknown	Newfoundland	unknown	Wang et al. (1996)
Phocids				
Harbour Seal	40,000-100,000 [c]	NW Atlantic	930	Reijnders et al. (1993); Boulva and McLaren (1979)
Grey Seal	154,000	E. Canada	unknown	Mohn and Bowen (1996)
Harp Seal	4.5-4.8 million	NW Atlantic	unknown	Shelton et al. (1996)
Hooded Seal	400,000-450,000	NW Atlantic	unknown	Stenson et al. (1996)

[a] Based on surveys from the Gulf of St. Lawrence.
[b] Based on surveys from Virginia to the Gulf of St. Lawrence.
[c] Mostly from the Maine coast (U.S.).

Table 3.10–3 Prey of Marine Mammals that Occur in the White Rose Study Area

Species	Prey	Source of Updated Information
Mysticetes		
North Atlantic Right Whale	Copepods (*Calanus* spp.), other zooplankton	Knowlton (1997)
Humpback Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Blue Whale	Euphausiids	
Fin Whale	Fish (predominantly capelin), euphausiids	Piatt et al. (1989)
Sei Whale	Copepods, euphausiids, some fish	
Minke Whale	Fish (predominantly capelin), squid, euphausiids	Piatt et al. (1989)
Odontocetes		
Sperm Whale	Cephalopods, fish	Reeves and Whitehead (1997)
Northern Bottlenose Whale	Primarily squid, also fish	
Killer Whale	Herring, squid, seals, dolphins, other whales	Lien et al. (1988)
Long-finned Pilot Whale	Short-finned squid, northern cod, amphipods	e.g. Nelson and Lien (1996)
Common Dolphin	Squid, fish (mackerel, butterfish)	Gaskin (1992)
Atlantic White-sided Dolphin	Schooling fish (sand lance, herring), hake, squid	Palka et al. (1997)
White-beaked Dolphin	Fish (cod, capelin, herring), squid	Hai et al. (1996)
Harbour Porpoise	Schooling fish (capelin, cod, herring, mackerel)	
Phocids		
Harbour Seal	Fish (primarily herring, flounder), squid, shrimp	Bowen and Harrison (1996)
Grey Seal	Fish (herring, cod, hake, pollock), squid, shrimp	Benoit and Bowen (1990); Hammill et al. (1995)
Harp Seal	Fish (capelin, cod, halibut, sand lance), crustaceans	Lawson and Stenson (1995); Lawson et al. (1998); Wallace and Lawson (1997); Hammill and Stenson (in press).
Hooded Seal	Fish (Greenland halibut, redfish, Arctic and Atlantic cod, herring), squid, shrimp, molluscs	Ross (1993)

Source: Mobil (1985) with updates where indicated.

Several recent studies (since 1995) have provided additional information on the feeding habits, population size and to a limited extent, the distributions of marine mammals within the study area and surrounding waters. One of these studies, "Marine Bird and Mammal Surveys on the Newfoundland Grand Bank from Offshore Supply Vessels" (Wiese and Montevecchi 1999), provides the most recent sighting information for several whale species in the study area. However, the data summarized in that report are limited for several reasons: the study focused on marine birds, data were only reported from August and September and the survey covered a limited route from St. John's to the White Rose area. Information from Wiese and Montevecchi (1999) and other recent studies is discussed below.

3.10.1 Mysticetes (Baleen Whales)

Six species of baleen whales or mysticetes occur in the study area: humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), minke (*B. acutorostrata*) and possibly North Atlantic right whale (*Eubalaena glaciais*) (Table 3.10-1). Although nearly all of these species experienced depletion due to whaling, it is likely that many are experiencing some recovery (Best 1993). However, the humpback, blue and fin whales are still listed as vulnerable and the North Atlantic right whale is listed as endangered by COSEWIC (1999).

3.10.1.1 North Atlantic Right Whale

The North Atlantic right whale is the most endangered species of large whale in the NW Atlantic and, consequently, has received the most attention of all the mysticetes in recent years. A recent population estimate for this species was 284 individuals in 1996 (Knowlton 1997). The latest mark-recapture study using photo-identified individuals suggests this population will become extinct within the next 191 years, given the current mortality and growth rate trends (Caswell et al. 1999). Although whalers historically took right whales off the coast of Newfoundland, recent sightings in these waters have been rare. Sightings of photo-identified individuals suggest that at least some proportion of the population pass through waters in and near the study area. An adult female was sighted at 48°35´N, 53°14´W in August 1981, and a mother and calf were sighted north of the study area (Labrador Basin) in August 1989 (Knowlton 1997). There is a possibility that an unknown 'nursery' area for these animals exists (Knowlton 1997; Waring et al. 1999), but the paucity of sightings in Newfoundland waters suggests it occurs (if at all) elsewhere.

3.10.1.2 Humpback Whale

The humpback whale has a cosmopolitan distribution. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). It is by far the most common baleen whale in Newfoundland waters. About 900 humpbacks are thought to use the Southeast Shoal of the Grand Banks as a summer feeding area, where their primary prey is capelin (Whitehead and Glass 1985). Thirteen humpbacks were sighted offshore during the offshore supply vessel survey in 1999; most of these sightings were in September (Wiese and Montevecchi 1999).

Recent research on humpbacks suggests genetic as well as spatial segregation between feeding areas within the North Atlantic (Valsecchi et al. 1997). The entire North Atlantic population is estimated at approximately 10,600 individuals (Smith et al. 1999), the northwest Atlantic population at 5,505 individuals (Katona and Beard 1990) and the Newfoundland/Labrador population at 1,700 to 3,200 (Whitehead 1982).

3.10.1.3 Blue Whale

The blue whale, which has likely always been rare in Canadian waters (Mansfield 1985), probably numbers in the few hundreds in the northwest Atlantic (Waring et al. 1999). It is rarely sighted on the Grand Banks. Nothing is known about trends in blue whale abundance in the northwest Atlantic, but the population that summers around Iceland has been increasing at approximately 5 percent/yr (Sigurjónsson and Gunnlaugsson 1990).

3.10.1.4 Fin Whale

The fin whale is found commonly in summer on the Grand Banks (Piatt et al. 1989). Eight fin whales, including two calves, were sighted on the Grand Banks in August 1999, during the offshore supply vessel survey (Wiese and Montevecchi 1999). This species is associated with the presence of capelin, their predominant prey item in these waters (Piatt et al. 1989; Whitehead and Carscadden 1985).

Recent genetic studies indicate that fin whale populations that summer in Nova Scotia, Newfoundland, and Iceland may be genetically distinct from each other (Arnason 1995). The number of fin whales in the northwest Atlantic was recently estimated at approximately 2,200 (Waring et al. 1999). This is lower than estimates from previous reports, but supports the idea that fin whale numbers are decreasing off Newfoundland (Whitehead and Carscadden 1985).

3.10.1.5 Sei Whale

The sei whale has a cosmopolitan distribution, and prefers temperate oceanic waters (Gambell 1985). Sei whales are known for their high mobility and unpredictable appearances (Reeves et al. 1998). Incursions into nearshore waters of the Gulf of Maine, associated with high copepod densities, are well documented (Payne et al. 1990; Schilling et al. 1992).

No reliable population estimates are available for sei whales; an estimate in the 1970s for the Nova Scotia stock suggested a minimum population of 870 individuals (Mitchell and Chapman 1977). This population is thought to range as far as the Grand Banks.

3.10.1.6 Minke Whale

Another baleen whale found commonly in summer on the Grand Banks is the minke whale (Piatt et al. 1989). Eight individuals were sighted along the near-shore half of the offshore supply vessel survey in August and September 1999 (Wiese and Montevecchi 1999). Like the fin whale, the minke whale is associated with the presence of capelin, their predominant prey item in these waters (Piatt et al. 1989; Whitehead and Carscadden 1985). The size of the northwest Atlantic population of minke whales is not well known, but the best available estimate is 2,790 individuals (Waring et al. 1999).

3.10.2 Odontocetes (Toothed Whales)

Eight species of odontocetes or toothed whales are found in the study area (Table 3.10-1). These species range from the largest living odontocete, the sperm whale (*Physeter macrocephalus*) (at approximately 18 m for an adult male (Reeves and Whitehead 1997)) to one of the smallest whales, the harbour porpoise (*Phocoena phocoena*) (at approximately 1.6 m for an average adult (Gaskin 1992a)). Most of these marine mammals occur seasonally in the study area and little is known regarding their distribution and population size in these waters. The harbour porpoise is listed as threatened and the Gully population (Nova Scotia) of the northern bottlenose whale (*Hyperoodon ampullatus*) is listed as vulnerable (COSEWIC 1999).

3.10.2.1 Sperm Whale

Sperm whales have an extensive worldwide distribution (Rice 1989). This species routinely dives to depths of hundreds of metres and may occasionally dive to more than 3,000 m. They apparently are capable of remaining submerged for longer than two hours, but most dives probably last a half-hour or less (Rice 1989). The diet of sperm whales is dominated by mesopelagic and benthic squids and fishes (Reeves and Whitehead 1997).

The number of sperm whales in the North Atlantic and in the study area is unknown. Reeves and Whitehead (1997) caution that previous population estimates for this species are suspect given their long-distance movements and lack of any clear stock structure. Evidence that stock delineation in this species may be dependent on the time scale of the measure used, further complicates obtaining reliable population estimates (Dufault et al. 1999).

3.10.2.2 Northern Bottlenose Whale

Northern bottlenose whales are found only in the North Atlantic, with a total population that may be in the tens of thousands (Reeves et al. 1993). Only a few individuals have been sighted on the Grand Banks. Like sperm whales, bottlenose whales can dive for periods well in excess of one hour and to depths of more than 1,000 m. They live primarily in deep canyon and slope areas, where they prey on squid and deep-sea fishes. Few bottlenose whales are expected to occur on the relatively shallow Grand Banks.

3.10.2.3 Killer Whale

The killer whale (*Orcinus orca*) is a year-round resident which, in contrast to the long-finned pilot whale, is thought to occur in relatively small numbers in the study area (Lien et al. 1988). Three killer whales were sighted within 20 km of the White Rose area on August 24, 1999 (Wiese and Montevecchi 1999). On a global basis, killer whales are not endangered. There are no population estimates for the northwest Atlantic.

3.10.2.4 Long-finned Pilot Whale

The most common odontocete in the area and also one of the only year-round residents is the long-finned pilot whale (*Globicephala melas*) (also known as the Atlantic pilot whale). This species is considered abundant in the Grand Banks area from July through December. However, none were sighted during the recent offshore supply vessel survey (Wiese and Montevecchi 1999). The northwest Atlantic population probably numbers between 4,000 and 12,000 individuals (Nelson and Lien 1996).

It is a common belief that long-finned pilot whales in the northwest Atlantic prey mainly on short-finned squid in summer. However, this statement is based largely on evidence from inshore waters of Newfoundland (Sergeant 1962), and other evidence suggests that they also prey on a variety of fish species, as well as additional species of cephalopods (especially long-finned squid, *Loligo pealei*) at other times and in other areas (Waring et al. 1990; Overholtz and Waring 1991; Desportes and Mouritsen 1993; Nelson and Lien 1996; Gannon et al. 1997).

3.10.2.5 Common Dolphin

A north-south migration has been assumed to occur along the east coast of North America, with common dolphins (*Delphinus delphis*) moving into higher-latitude areas in summer and fall, then moving farther south (or possibly just offshore) for the winter (Selzer and Payne 1988; Gowans and Whitehead 1995). The northern limit of this species range in the summer is likely the Flemish Cap (Gaskin 1992c). Areas with steep subsurface relief, generally in a broad band paralleling the continental slope (100 to 200 m depth contour), tend to have relatively high densities of short-beaked common dolphins in U.S. waters (Selzer and Payne 1988).

The common dolphin in the northwest Atlantic probably numbers in the low tens of thousands (Waring et al. 1999). The number occurring in the study area is unknown.

3.10.2.6 Atlantic White-Sided Dolphin

There are three stocks of Atlantic white-sided dolphins (*Lagenorphynchus acutus*) in the northwest Atlantic; Gulf of Maine, Gulf of St. Lawrence and Labrador Sea. The combined northwest Atlantic population probably numbers 27,000 individuals (Palka et al. 1997). The number of white-sided dolphins in the study area is unknown. There were seven sightings of 250 individuals on the Grand Banks in August to September 1999, including several sightings within approximately 30 km of the White Rose site, during the offshore supply vessel surveys (Wiese and Montevecchi 1999). The most easterly recorded sighting for individuals from the northwest Atlantic population occurred on the Flemish Cap (Gaskin 1992b).

3.10.2.7 White-beaked Dolphin

The white-beaked dolphin (*Lagenorhynchus albirostris*) tends to be a coastal, cool-water species (Reeves et al. 1999). This species seems to remain at relatively high latitudes throughout the fall and winter (Lien et al. 1997), but the nature of their seasonal movements is uncertain. During the summer, approximately 3,500 white-beaked dolphins have been estimated to occur off southern Labrador (Alling and Whitehead 1987). This species was regularly sighted in the study area during the 1980-81 Hibernia surveys, primarily during summer (Mobil 1985). There is no reliable population estimate for the study area or the entire northwest Atlantic. The total North Atlantic population may range from high tens of thousands to low hundreds of thousands (Reeves et al. 1999). Ice entrapment is not uncommon in the bays of southern Newfoundland in years when pack ice is heavy (Hai et al. 1996).

3.10.2.8 Harbour Porpoise

The harbour porpoise is widely distributed throughout temperate waters, but its population size in Newfoundland waters is unknown (Gaskin 1992a). Harbour porpoises that occur in Newfoundland waters are believed to belong to a separate stock from those in the Gulf of St. Lawrence and Bay of Fundy/Gulf of Maine regions. This is supported by differences in organochlorine contaminant levels, which are lower in Newfoundland animals (Westgate and Tolley 1999), and by differences in mitochondrial DNA haplotype frequencies (Wang et al. 1996).

3.10.3 Phocids (True Seals)

Four species of phocids or true seals occur regularly in waters off Newfoundland (Table 3.10-1). Populations of grey (*Halichoerus grypus*), harp (*Phoca groenlandica*) and hooded (*Cystophora cristata*) seals in Canada, and harbour seals (*Phoca vitulina*) in the United States, are thought to be increasing (Waring et al. 1999). Because of their potential to interact with commercial fisheries, reasonable population estimates for the northwest Atlantic are now available for most seal species (Table 3.10-2). The main diet of seals consists of fish (including capelin, cod, halibut and sand lance) and invertebrates such as squid and shrimp (Table 3.10-3), with considerable seasonal, geographic and interannual variation in diet (Hammill et al. 1995; Lawson and Stenson 1995; Wallace and Lawson 1997). Recent research on various aspects of the biology of the different seal species is discussed below.

3.10.3.1 Harbour Seal

The harbour seal is a relatively small phocid species that has a broad distribution that spans much of the temperate Northern Hemisphere. Harbour seals are year-round residents along the south coast of Newfoundland. Recent information on the distribution and population size of harbour seals off Newfoundland and in the study area is lacking (Stenson 1994). In 1973, approximately 930 harbour seals were estimated to be present in coastal areas of the study area, primarily in St. Mary's and Placentia Bay (Boulva and McLaren 1979). More than 700 seals were regularly observed hauled out during the early 1980s breeding season in a sandy bay, the Grand Barachois, on the Island of Miquelon (45°45´N, 56°14´W), just west of the study area (Renouf et al. 1983). In May and early June, approximately 150 pups were born at this location (Renouf et al. 1983). No new information is available for harbour seals on Miquelon (W.D. Bowen, pers. comm.), but it is believed the number of seals using this site is declining (J.W. Lawson, pers. comm.). In general, harbour seals have a varied diet, including pelagic and demersal fish as well as cephalopods and crustaceans (see, for example, Boulva and McLaren 1979; Bowen and Harrison 1996).

Harbour seals are not endangered; COSEWIC lists the Atlantic Canadian population as "Indeterminate". There is no reliable estimate for the number of harbour seals occurring in eastern Canada. There is thought to be a single stock in the northwest Atlantic from the Arctic to the New England region. There are approximately 40,000 to 100,000 in the northwest Atlantic (Reijnders et al. 1993). The population along the Maine coast (that is, U.S. waters) numbers around 31,000 (estimated in 1997) and appears to be increasing (Waring et al. 1999).

3.10.3.2 Grey Seal

Grey seals in the study area are migrants from the Sable Island and Gulf of St. Lawrence breeding populations. This species occurs in the study area year-round, but most commonly in July and August (Stenson 1994). In the past, grey seals were regularly observed hauled out at Miquelon during the summer (Renouf et al. 1983). At present, it is unknown how many grey seals use this site (J.W. Lawson, pers. comm.). The Sable Island and Gulf of St. Lawrence breeding areas account for essentially all of the pup production in the northwest Atlantic, which increased exponentially between 1977 and 1989 (Stobo and Zwanenburg 1990). The eastern Canadian population of grey seals was estimated at 154,000 in 1994 (Mohn and Bowen 1996). The number that migrates into the study area is unknown, but is believed low.

Grey seals are less tied to coastal and island rookeries than are harbour seals. They travel long distances, one individual having been tracked over a distance of 2,100 km (McConnell et al. 1999). The food of grey seals in the western North Atlantic includes at least 40 species, some of which are commercially important (for example, Atlantic cod, herring, and capelin) (Benoit and Bowen 1990; Hammill et al. 1995).

3.10.3.3 Harp Seal

Harp seals whelp in the spring in the Gulf of St. Lawrence and in an area known as the 'Front' off southern Labrador and northeastern Newfoundland (Sergeant 1991). Individuals from these two areas spend the summer in the Arctic and then migrate south in the autumn. Surveys conducted during the early 1990s suggested that offshore waters on the northern edge of the Grand Banks in NAFO fishing area 3L were an important over-wintering area for these animals during those years (Stenson and Kavanagh 1994). Sighting effort from these surveys within the study area was low, but harp seals were present in low numbers in the study area. Similarly, data from satellite transmitters deployed on harp seals suggest that the Grand Banks is an important wintering area for some seals (Stenson and Sjare 1997). It is possible that more harp seals are occurring south of this area in recent years because there has been an apparent change in their distribution. There has been a documented increase in the extralimital occurrences (south of normal range) of harp seals in the northern Gulf of Maine (McAlpine et al. 1999), which may also be occurring in the Grand Banks area. This southward expansion may be related to the increase in the harp seal population or the recent changes in ocean ecology that may be affecting their foraging success (McAlpine et al. 1999).

In 1994, the total population estimate of harp seals in the northwest Atlantic was 4.5 million to 4.8 million, with a suggested growth rate of approximately 5 percent/yr since 1990 (Shelton et al. 1996).

The diet of harp seals foraging off Newfoundland and Labrador appears to vary considerably with age, season, year and location. On the Grand Banks and Labrador Shelf, capelin predominate, followed by sand lance, Greenland halibut and other pleuronectids (Wallace and Lawson 1997; Lawson et al. 1998). Recent “historical” data on the diet of harp seals greater than a year old from northeast Newfoundland, indicates that there was a shift in prey from capelin in 1982 to Arctic cod in 1986 and beyond, while Atlantic cod remained relatively unimportant throughout this period. Harp seals collected from nearshore waters forage intensively on a variety of fish and invertebrate species, although most of the biomass is derived from relatively few species, particularly Arctic cod, capelin, Atlantic cod, Atlantic herring and some decapod crustaceans. A recent consumption model estimates that harp seals consume less Atlantic cod than once believed as seals apparently spend more time offshore (Hammill and Stenson, in press).

3.10.3.4 Hooded Seal

Like the harp seal, the hooded seal is a North Atlantic endemic species that reproduces on the spring pack ice of the Gulf of St. Lawrence and along the Labrador coast, then migrates northward to the sub-Arctic and Arctic to feed during the summer (Lydersen and Kovacs 1999). Data collected from satellite transmitters deployed on hooded seals in the Gulf of St. Lawrence indicate that some females feed near the Flemish Cap after breeding while migrating to Greenland waters (G.B. Stenson, unpubl. data). Tagged males migrating to Greenland in early summer were recorded along the Grand Banks shelf edge near the Flemish Pass. It appears that males spend little time foraging in this area (G.B. Stenson, unpubl. data.). Little is known regarding their winter distribution, although it is believed that the majority of seals remain offshore; they have been seen feeding off the Grand Banks in February. Surveys in the early 1990s suggested that, as was the case for harp seals, the offshore waters on the northern edge of the Grand Banks also might be an important over-wintering area for hooded seals (Stenson and Kavanagh 1994). Hooded seal sightings in the study area during these surveys were less frequent than harp seal sightings. The number of visitors to the study area is unknown, but presumed low. However, these numbers may be increasing as hooded seals are apparently expanding their southern range of occurrence (McAlpine et al. 1999).

The most recent (1990) estimate of pup production at “the Front” off Labrador was approximately 83,000 (Stenson et al. 1997), suggesting a current total population of hooded seals in the northwest Atlantic of 500,000 (Whitehead et al. 1998).

Hooded seals consume a variety of prey. In nearshore areas of Newfoundland, prey (in decreasing order of total wet weight) includes: Greenland halibut, redfish, Arctic cod, Atlantic herring and capelin. Relatively small amounts of squid (*Gonadus* spp.) and Atlantic cod were also found (Ross 1993). Data from offshore areas are limited, but suggest that similar prey species are consumed (J.W. Lawson and G.B. Stenson, unpubl. data).

3.11 SEA TURTLES

Three species of sea turtles are known to occur in the study area: leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*) and Kemp’s ridley (*Lepidochelys kempii*) (Ernst et al. 1994). The leatherback turtle is listed as endangered by COSEWIC (1999) and by the United States National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS) (Plotkin 1995). The Kemp’s ridley is also listed as endangered and the loggerhead turtle is listed as threatened by NMFS and FWS (Plotkin 1995).

3.11.1 Leatherback Turtle

The leatherback is the largest living turtle (2.2 m in length and over 900 kg (Morgan 1989) and it also may be the most widely distributed reptile, as it ranges throughout the Atlantic, Pacific, and Indian oceans and into the Mediterranean Sea (Ernst et al. 1994). Adults engage in routine migrations between temperate and tropical waters, presumably to optimize both foraging and nesting opportunities. Leatherbacks are less genetically diverse than other sea turtle species and may have less-rigid homing instincts (Dutton et al. 1999).

The worldwide population of leatherbacks is currently estimated at between 26,000 and 43, 000 (Dutton et al. 1999). The current population is thought to be declining as major nesting colonies have declined in the last 20 years, although an increase in leatherbacks nesting in Florida has been reported in the last few years (Dutton et al. 1999). Despite its patchy worldwide distribution and in contrast to other sea turtles, adult leatherbacks are regularly sighted in the waters off Nova Scotia and Newfoundland from June to October (with peak abundance in August), where they likely come to feed on jellyfish, their primary prey (Bleakney 1965; Cook 1981; 1984). The scattered nature of the data make estimating the number of turtles in the Canadian Atlantic difficult. However, the North Atlantic Leatherback Turtle Working Group (NALTWG), created in 1997, is currently conducting research on the distribution and abundance of the leatherback. Apparently, more leatherbacks visit waters near the study area than was once believed (M. James, pers. comm.). An adult male that was satellite-tagged in waters near Cape Breton Island, Nova Scotia in early September 1999, travelled to Placentia Bay, Newfoundland by the end of the month before migrating south to warmer waters. Data from the U.S. pelagic longline fishery observer program have also added to the knowledge of leatherback distribution off Newfoundland (Witzell 1999). Nearly half of the leatherbacks (593 captures) caught incidentally by this fishery between 1992 and 1995 from the Caribbean to Labrador were captured in waters on and east of the 200-m isobath off the Grand Banks (Witzell 1999). Animals were caught in this region during all months from June to November, with the bulk of captures from July to September. Not surprisingly, leatherback captures within these waters corresponded closely with fishing effort, both clustered near the 200-m isobath.

The apparent common northerly occurrence of this species compared to other sea turtles may be attributed to an ability to maintain body temperatures of 25ºC in sea water as much as 18ºC cooler. An adult was even observed by fishermen in Trinity Bay, Newfoundland swimming amongst ice (Goff and Lien 1988). Twenty leatherbacks were reported off Newfoundland between 1976 to 1985, 14 were entangled in fishing gear (Goff and Lien 1988).

Little is known about the biology of the leatherback. It nests from April through November in the tropics along sandy beaches. Females deposit an average of five to seven nests per year, with clutch size averages varying geographically (Plotkin 1995). Nothing is known about the behaviour or survivorship of post-hatchlings. Loss of nesting habitat due to development and erosion, predation by animals, and poaching of adults and eggs for consumption inhibit the recovery of this species. Ingestion of plastic materials, which leatherbacks presumably mistake for jellyfish is common and can be fatal. The loss of individuals (primarily through net entanglement) in the Canadian Atlantic is not known to critically contribute to population decline (Cook 1981).

3.11.2 Loggerhead Turtle

This species is the most abundant sea turtle in North American waters (Ernst et al. 1994; Plotkin 1995). The loggerhead turtle winters in the south, but some individuals migrate north into the Canadian Atlantic with the Gulf Stream in summer (Cook 1984). An estimate of the population size in the study area is unavailable; however, loggerheads are thought to occur in these waters during summer and fall. Loggerheads found in Canadian waters are generally smaller than those found in coastal U.S. waters, indicating they are younger animals (Witzell 1999).

Loggerhead turtles apparently dwell in both coastal and offshore waters but generally associate with convergence zones, drift lines and downwellings (Carr 1986). Continental shelf waters like those in the study area are believed to be important because they contain known loggerhead prey like crabs, molluscs, sea pens and various gelatinous organisms (Payne et al. 1984). Loggerheads also eat algae and vascular plants (Ernst et al. 1994). Data from the U.S. pelagic longline fishery observer program have added to the knowledge of loggerhead distribution off Newfoundland (Witzell 1999). Seventy percent of loggerheads (936 captures) caught incidentally by this fishery between 1992 and 1995 from the Caribbean to Labrador were captured in waters on and east of the 200-m isobath off the Grand Banks. Animals were caught in this region during all months from June to November, with a peak in captures during September. Within these waters, loggerhead captures corresponded closely with fishing effort, both clustered near the 200-m isobath where oceanographic features lead to the concentration of prey species for both the turtles and the swordfish and tuna that are the targets of the longline fishers.

There is no worldwide population estimate for this species, but numbers of loggerheads outside of the U.S. are declining (Plotkin 1995). The North American population, which is also thought to be declining, has been estimated to number between 9,000 and 50,000 adults (Ernst et al. 1994). It is estimated that 5,000 to 50,000 loggerheads are killed annually by offshore shrimp trawls in the southeastern U.S. and the Gulf of Mexico (Magnuson et al. 1990).

The loggerhead turtle may achieve sexual maturity at an age of 30 to 50 years and one of the largest breeding aggregations is found on the central Atlantic coast of Florida (Magnuson et al. 1990). In fact, 90 percent of females nesting in the Atlantic do so in the southeastern U.S. in what appear to be demographically independent groups (based on mitochondrial DNA haplotype distributions) (Encalada et al. 1998). Most females nest from three to five times in a season and average clutch sizes are between 95 to 150 eggs per nest (LeBuff 1990).

3.11.3 Kemp's Ridley Turtle

Kemp's ridleys are the smallest (40 to 50 kg) and rarest of all sea turtles within the study area (Cook 1984). These turtles apparently prefer shallow water and while adults rarely range beyond the Gulf of Mexico, juveniles have been sighted along the southeast coast of Newfoundland near St. Mary's Bay and along southern Nova Scotia (Ernst et al. 1994). However, the number of Kemp's ridley turtles that visit the study area is unknown. They apparently prefer shallow water and feed primarily on crabs, but occasionally they eat molluscs, fish, shrimp and vegetation (Shaver 1991).

This species has a very restricted nesting range, with 95 percent of nests laid along a 60 km stretch of beach in Rancho Nuevo, Mexico. The number of females nesting there declined from as many as 40,000 over 50 years ago to approximately 700 in the late 1980s, but saw a steady increase in the 1990s as a result of conservation measures (Marquez et al. 1999). It is unknown how long this species lives or at what age it reaches sexual maturity. More than half of the adult females nest every year between April and August (NRC 1990). They lay an average of 3.1 clutches per season, with an average of 103 eggs per clutch (Rostal 1991). After a 48 to 65 day incubation period, eggs hatch and hatchlings head for the sea (Mager 1985). Both eggs and hatchlings are very vulnerable to predators like ghost crabs, coyotes and hawks (Plotkin 1995). Of greater concern is the incidental capture of turtles in shrimp trawls, despite efforts to deter turtles from areas where trawls are in use.

4 EFFECTS ASSESSMENT

4.1 TYPES OF EFFECTS

Two general types of effects are considered in this document:

1. Effects of the project on the environment, particularly the biological environment; and

2. Effects of the environment, particularly the physical environment, on the project are discussed in more detail in Chapter 1 of the Comprehensive Study and Section 4.3.1.1 (biofouling) of this document. A detailed description of the Physical Environment is given in Chapter 2 of this document.

The biological environment is emphasized because the fish, marine mammals and birds of the Grand Banks area are of great interest and value to society (and are considered Valued Environmental Components (VECs)). These vertebrates are also good indicators of the health of the marine system upon which they depend. Benthic invertebrates are considered within fish and fish habitat. The effects on each VEC are described in separate chapters in the following assessment.

Socio-economic effects, including those on the commercial fisheries, are considered in the SEIS (Part Two). Social and economic benefits of the development are also contained in the SEIS (Part Two).

4.2 METHODOLOGY

Methods of effects assessment are generally comparable to those used in both the Hibernia and Terra Nova EIS. They conform to the *Canadian Environmental Assessment Act* (CEAA) and its associated Responsible Authority's Guide (1994a), and Preparation of a Comprehensive Study (1997) and Preparation and Management of Comprehensive Studies under *Canadian Environmental Assessment Act* (1998) as well as CEAA (1998a; 1998b). Cumulative effects are incorporated within the procedures in accordance with CEAA (CEAA 1994c) and as adapted from Barnes and Davey (1999). The specifications and spirit of these documents have been followed in preparing this EIS. Detailed methods are described in the following sections.

4.2.1 Valued Environmental Components

4.2.1.1 Selected Valued Environmental Components

It is not possible to address the potential interactions between every project activity and every component of the natural and human environment. Thus, the EIS focuses on important VECs. However, effects are assessed on other elements of the ecosystem such as water quality, plankton and benthos, where relevant to VECs such as fish and fish habitat. VECs are discussed extensively in Beanlands and Duinker (1983).

VECs include the following groups:

- rare or threatened species or habitats;
- species or habitats that are unique to an area, or are valued for their aesthetic properties; and
- species that are harvested by people.

VECs were identified based on the Hibernia EIS (Mobil 1985), the Terra Nova EIS (Petro-Canada 1995) and through research by the White Rose environmental assessment team. The results of the issue scoping sessions were considered in identifying the VECs for assessment. The VECs considered in this EIS include:

- fish and fish habitat (with focus on commercial species);
- marine birds;
- marine mammals; and
- sea turtles.

Several sections also discuss effects on air quality, water quality, planktonic and benthic animals. These important elements of the ecosystem that support higher trophic levels (VECS such as fish, birds, mammals and turtles) are not considered VECs for impact assessment purposes. Benthic animals, with the exception of shellfish, are not VECs. However, as they are not mobile, they can be more readily assessed than the mobile VECs listed above. Benthic animals are good indicators of possible development effects on VECs, particularly fish habitat, at, in or on the seabed, and also can indicate the likelihood of effects on VECs. The commercial (economic) aspects of the fishery are detailed in Chapter 7 of the SEIS (Part Two).

4.2.1.2 Rationale for Selection

The biophysical VECs were selected based upon expressed public concerns related to social, cultural, economic, or aesthetic values and scientific community concerns. As described in previous sections, public concerns were captured during the extensive public consultation effort that included both open and invited sessions. Additional scientific concerns were assembled through literature reviews (particularly previous offshore EIS, Hibernia, Terra Nova, Scotian Shelf, and associated documents) and meetings within the study team and with government scientists and other stakeholders. These concerns were assembled and refined by the study team using professional judgement in combination with CEAA guidance documents. Rationale associated with specific VECs is shown below.

- **Fish and Fish Habitat**. The commercial fishery is a universally acknowledged and important element in society, culture, economic and aesthetic environment of Newfoundland and Labrador. The fish and fish habitat upon which the commercial fishery is based is a typical VEC assessed in an EIS for a project impinging on aquatic environments (for example, Hibernia and Terra Nova EIS). It should be noted that this broad VEC includes coverage of such components of fish habitat as water quality and benthos. Many of the issues listed in the summary table of issue and concerns (Comp Study Table 1.5-1) are linked directly or indirectly to commercial fish and/or fishery. This VEC is of prime concern from both a public and scientific perspective, locally, nationally and internationally.

- **Marine Birds**. Newfoundland supports some of the largest seabird colonies in the world and the Grand Banks hosts very large populations during all seasons. They are important socially, culturally, economically, aesthetically, ecologically and scientifically. Seabirds are a key component near the top of the food chain and are an important resource for bird watching (one of the fastest growing outdoor activities in North America), the tourist industry, local hunting, and scientific study. In addition, this VEC is more sensitive to oil on water than other VECs. Many of the issues and concerns listed in Comp Study Table 1.5-1 are directly related to seabirds. This VEC is of prime concern from both a public and scientific perspective, locally, nationally and internationally.

- **Marine Mammals**. Whales and seals are key elements in the social and biological environments of Newfoundland and Labrador. The economic and aesthetic importance of whales is evidenced by the large number of tour boats that feature whale watching as part of a growing tourist industry. Public concern about whales is evident in the media on an almost daily basis. Historically, seals have played an important economic and cultural role due to the large annual seal hunt. Newfoundland and Labrador is an internationally recognized location for marine mammal scientific research. Although not expressly reflected in the public consultations (see Comp Study Table 1.5-1), this VEC is also of prime concern from both a public and scientific perspective, locally, nationally and internationally.

- **Sea Turtles**. While sea turtles are scarce on the Grand Banks in general, they attain status of a VEC because of their endangered and threatened status in Canada, the United States and elsewhere. Of the three species present on the Grand Banks, two are considered endangered and one threatened. While they are of little or no economic, social or cultural importance to Newfoundland and Labrador (no direct issues in Comp Study Table 1.5-1), their status ensures local, national, and international scientific attention beyond their likely ecological importance to the Grand Banks ecosystem.

4.2.2 Boundaries

Effects are assessed for the three-year development phase to First Oil and the expected 12 to 14-yr production lifespan of the White Rose Development. Effects that could continue after decommissioning are also considered. In addition, effects of accidental events are considered. The spatial boundaries of the assessment include the Grand Banks and existing areas being considered for onshore facilities. For accidental oil spills, the effects were assessed for all areas that could be affected by a spill or loss of well control at White Rose, as determined through oil spill modelling. The regional assessment boundaries are the Grand Banks as defined by the Hibernia and Terra Nova study area (Figure 3-1). Boundaries for this assessment were previously discussed in Section 1.2.2 of the Comprehensive Study. The administrative boundaries are determined by federal and provincial legislation. Technical boundaries are determined by constraints inherent in the scientific and technical literature and by the zone of influence (ZOI) modelling for cuttings and produced water discharges, and oil spill modelling. Technical boundaries are discussed within the appropriate sections.

4.2.3 Effects Assessment Procedures

Procedures for the effects assessment were according to the CEA Agency (CEAA 1994a; 1994b, 1994c; 1998a; 1998b; 1998c; 1999), Duffy (1986), the Federal Environmental Assessment and Review Office (FEARO) (1976; 1978) and adapted from Barnes and Davey (1999). Assessment of the potential effects of each project phase involved three major steps:

1. preparation of interaction (between project activities and the environment) matrices;
2. identification and evaluation of potential effects including description of mitigation measures and residual effects; and
3. preparation of residual effects summary tables, including evaluation of cumulative effects.

4.2.3.1 Preparation of Interaction Matrices

Interaction matrices were prepared for the development, production and decommissioning components of the project. An interaction matrix identifies all possible project activities that could interact with any of the VECs (see, for example, Table 4.3-1). The matrices include times and places where interactions could occur. The interaction matrices are used only to identify potential interactions; they make no assumptions about the potential effects of the interactions.

4.2.3.2 Identification and Evaluation of Effects

Interactions identified in the Level I matrices were then evaluated for their potential to cause effects. In instances where the potential for an effect of an interaction was deemed impossible or extremely remote, these interactions were not considered further. In this way, the assessment could focus on key issues and the more substantive environmental effects as specified by C-NOPB guidelines (1988) and the scoping document (2000) (Appendix 1.A of the Comprehensive Study).

An interaction was considered to be a potential effect if it could change the abundance or distribution of VECs, or change the prey species or habitats used by VECs. The potential for an effect was assessed by a discipline expert who considered:

- the location and timing of the interaction;
- ZOI and oil spill modelling exercises;
- the literature on similar interactions and associated effects (including the Hibernia and Terra Nova EIS);
- when necessary, consultation with other experts; and
- results of similar effects assessments and especially, monitoring studies done in other areas.

When data were insufficient to allow certain or precise effects evaluations, predictions were made based on professional judgement. In such cases, the uncertainty is documented in the EIS. For the most part, the potential effects of offshore oil developments are reasonably well known.

The effects are presented as predictions based on the literature. In some cases, the predictions have also been examined by modelling. Information on monitoring programs to confirm predictions are presented in Chapter 7 of this document.

Effects were evaluated for the proposed development design, which includes many mitigation measures that are mandatory or have become standard operating procedure in the industry.

4.2.3.3 Classifying Anticipated Environmental Effects

The concept of classifying environmental effects simply means determining whether they are adverse or positive. The following includes some of the key factors that are considered for determining adverse environmental effects, as per the CEA Agency guidelines (CEAA 1994b):

- negative effects on the health of biota;
- loss of rare or endangered species;
- reductions in biological diversity;
- loss or avoidance of critical/productive habitat;
- fragmentation of habitat or interruption of movement corridors and migration routes;

- transformation of natural landscapes;
- discharge of persistent and/or toxic chemicals;
- toxicity effects on human health;
- loss of, or detrimental change in, current use of lands and resources for traditional purposes;
- foreclosure of future resource use or production; and
- negative effects on human health or well-being.

4.2.3.4 Mitigation

Most significant effects can be mitigated by additions to or changes in equipment, operational procedures, timing of activities, or other measures. Mitigation measures appropriate for each effect predicted in the matrix were identified and the effects of various project activities were then evaluated assuming that appropriate mitigation measures are applied. Residual effects predictions were made taking into consideration both standard and project-specific mitigations.

Mitigation includes environmental design, environmental protection strategies, and mitigation specific to the minimization or control of potential adverse environmental effects to a particular VEC. As required by CEAA, these measures must be technically and economically feasible. In this EIS, mitigation measures were identified using all available information. Implementation details will be contained in the final environmental protection plan (EPP) (see Chapter 8 for detail). In the case of positive effects, enhancement opportunities are considered.

4.2.3.5 Application of Evaluation Criteria for Assessing Environmental Effects

Several criteria were taken into account when evaluating the nature and extent of environmental effects. These criteria include (CEAA 1994b; 1994c):

- magnitude;
- geographic extent;
- duration and frequency;
- reversibility; and
- ecological, socio-cultural and economic context.

Each criterion has a numeric descriptor in the key of the environmental effects assessment matrix to simplify the presentation of results of the environmental assessment.

Magnitude describes the nature and extent of the environmental effect for each activity. Negligible effects were also identified. Geographic extent refers to the area affected by the project. Duration and frequency describe how long and how often a project activity and/or environmental effect will occur. Reversibility refers to the ability of a VEC to return to an equal, or improved condition, at the end of the project life cycle (for example, reclaiming habitat area equal or superior to that lost during construction). The ecological, socio-cultural and economic context describes the current status of the area affected by the project in terms of existing environmental effects. Two tables are provided for each VEC, indicating the results of the effects analysis and the significance of those effects for each phase of the project development (to First Oil), production and decommissioning (see, for example, Table 4.3-2). Effects predictions for accidental events are provided in Section 5.9.2 for all EIS VECs.

Magnitude was defined as:

Low = Affects 0 to 10 percent of individuals in the affected area (see geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance.

Medium = Affects 10 to 25 percent of individuals in the affected area (see geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance.

High = Affects more than 25 percent of individuals in the affected area (see geographic extent). Effects can be outright mortality, sublethal or exclusion due to disturbance.

Definitions of magnitude used in this EIS have been used previously in numerous offshore oil-related environmental assessments under CEAA. These include assessments of seismic surveys (Davis et al. 1998), exploratory drilling (Thomson et al. 2000) and production (Petro-Canada 1996). Terrestrial assessments under CEAA using this methodology are contained in LGL (1998). These magnitude definitions have also been used under FEARO auspices (for example, CCG 1991; Consulting and Audit Canada 1993; LGL 1991; 1996).

4.2.4 Cumulative Effects

Cumulative environmental effects are addressed for each project activity within each VEC section in varying levels of detail, depending upon the amount of information available, the results of issue scoping sessions, and potential for interaction of the activity with the VECs.. The projects and activities considered are those which are ongoing or likely to proceed, and have therefore been issued permits, licenses, leases, or some other form of approval, as specified by the CEA Agency in the "Reference Guide: Addressing Cumulative Effects" included in the "Responsible Authority's Guide" (CEAA 1994b) and the updated Practioner’s Guide (CEAA 1999).

Projects and activities considered in the cumulative effects assessment included:

- White Rose within-project cumulative impacts, particularly between the three project phases: (1) development, (2) production, and (3) decommissioning and abandonment and for accidental events. For the most part, and unless otherwise indicated, within-project cumulative assessment is fully integrated within the White Rose assessment;

- Hibernia (an existing offshore oil development on the Grand Banks);
- Terra Nova (an in-progress offshore oil development on the Grand Banks between Hibernia and White Rose);
- offshore oil exploration activity (seismic surveys and exploratory drilling). On the Grand Banks for 2000-2001, there are four approved seismic (J. McIntyre, pers. comm.) and three approved drilling programs and it is assumed that a similar level of activity will continue for the foreseeable future. [Note that there are 24 current exploration licences for the Grand Banks (C-NOPB website, June 9, 2000).];
- commercial fisheries (also see SEIS (Part Two));
- marine transportation (tankers, cargo ships, supply vessels, fishing vessel transits, etc.); and
- (for marine birds) hunting activities.

The above projects and activities have all received some form of formal approval and thus can be considered ongoing or likely to proceed as per CEAA (1994a; 1999).

4.2.5 Integrated Residual Environmental Effects

Upon completion of the evaluation of environmental effects, the residual environmental effects (effects after project-specific mitigation measures are imposed) are assigned a rating of significance for:

- each project activity or accident scenario;
- the cumulative effects of project activities within each phase of the project (development, operation, and decommissioning) and for all phases of the project combined; and
- the cumulative effects of combined projects within the study area.

These ratings are presented in summary tables of residual environmental effects. The last of these points considers all residual environmental effects, including project and other-project cumulative environmental effects. As such, this represents an integrated residual environmental effects evaluation.

The analysis and prediction of the significance of environmental effects, including cumulative environmental effects, encompasses the following:

- determination of the significance of residual environmental effects;
- establishment of the level of confidence for prediction; and
- evaluation of the scientific certainty and probability of occurrence of the residual impact prediction.

Ratings for level of confidence, probability of occurrence, and determination of scientific certainty associated with each prediction are presented in the tables of residual environmental effects (see, for example Table 4.3-3). The guidelines used to assess these ratings are discussed in detail in the sections below.

4.2.5.1 Significance Rating

Significance environmental effects are those that are considered to be of sufficient magnitude, duration, frequency, geographic extent, and/or reversibility to cause a change in the VEC that will alter its status or integrity beyond an acceptable level. Establishment of the criteria is based on professional judgement, but is transparent. In this EIS, a *significant* effect is defined as:

> *Having a high magnitude or medium magnitude for a duration of greater than one year and over a geographic extent greater than 100 km^2* (see Section 4.2.3.5 for further details).

An effect can be considered *significant*, *not significant*, or *positive.*

4.2.5.2 Level of Confidence

The significance of the residual environmental effects is based on a review of relevant literature, consultation with experts, and professional judgement. In some instances, making predictions of potential residual environmental effects is difficult due to the limitations of available data (for example, technical boundaries). Ratings are therefore provided to indicate, qualitatively, the level of confidence for each prediction.

4.2.5.3 Determination of Whether Predicted Environmental Effects Are Likely To Occur

It is important to assess the likelihood that significant adverse residual environmental effects will occur. It is also important to assess the degree of scientific certainty that underpins each prediction of impact significance. In keeping with CEA Agency guidelines documentation (CEAA 1994a; 1994c), the following criteria for the evaluation the likelihood of predicted effects are used.

- probability of occurrence; and
- scientific certainty.

Where possible, it is desirable to apply rigorous scientific and/or statistical methods to determine the likelihood of predicted residual environmental effects. However, in most cases such methods are not feasible; therefore it is necessary to use a qualitative approach or professional judgement. Where appropriate, an indication of the scientific certainty associated with the determination of likelihood is made based on reference to scientific knowledge, statistical significance, quantitative risk assessment, or professional judgement.

4.2.6 Monitoring and Follow-Up

As part of the environmental effects assessment, appropriate VEC-specific monitoring and follow-up are described. In developing a program, the results of the environmental effects assessment (and residual effects assessment) are helpful in focusing on important interactions, where there is a high level of uncertainty about environmental effects predictions, where significant environmental effects are predicted, or on areas of particular sensitivity. Monitoring and follow-up are discussed in detail in Chapter 7 of the EIS.

4.3 FISH AND FISH HABITAT VEC

In this biophysical EIS, commercial fish and their habitat are considered as one VEC, as they are inter-related. This approach also minimizes repetition and aids brevity. The effects assessment of the commercial fisheries, with focus on socio-economic aspects, is contained in the SEIS (Part Two).

Existing conditions for fish and fish habitat are contained in the previous sections and the commercial nature of those related fisheries is contained in the SEIS (Part Two). In the following sections, the effects of the White Rose development, production and abandonment phases are evaluated. Cumulative effects are also considered within the project and in consideration of Hibernia (an existing project), Terra Nova (an in-progress project), exploration activities, marine transportation and fisheries. Potential interactions between project activities and important elements of the ecosystem are shown in Table 4.3-1. In general, all three oil developments will have similar effects on the biophysical environment of the Grand Banks, ranging in magnitude and duration. Exploration activities, marine transportation and fisheries are also considered in terms of cumulative effects.

4.3.1 Effects of Routine Development Operations (Drilling and Construction)

The first phase of project development is drilling and construction to First Oil. The following sections examine in detail the effects of drilling and construction activities on fish and fish habitat. The interactions matrix in Table 4.3-1 shows potential interactions *only* and makes no judgement as to potential effects. Potential effects are evaluated in Table 4.3-2 for extent, duration and magnitude, frequency, reversibility, and ecological/socio-cultural and economic context and significance of those effects are predicted in Table 4.3-3.

Table 4.3-1 Potential Interactions Between the Project and Fish and Fish Habitat VEC

Valued Environmental Component: Fish and Fish Habitat									
	Habitat			Feeding		Reproduction		Adult Stage	
	Water Quality	Sediment	Topography	Plankton	Benthos	Eggs/Larvae	Juveniles	Pelagic Fish	Groundfish
Project Activities and Physical Works									
A. DEVELOPMENT PHASE									
Presence of Structures									
No Fishing Zone					x		x	x	x
Artificial Reef Effect					x		x	x	x
Subsea Structures			x		x				
Lights and Flares				x		x	x	x	
Underwater Construction	x	x	x		x				x
Drilling Mud/Cuttings									
Water-Based Mud	x	x	x	x	x	x			x
Synthetic-Based Mud	x	x	x	x	x	x			x
Other Fluids and Solids									
Completion, Packer and Workover	x			x	x	x		x	x
Cement					x				
BOP Fluid	x			x	x	x		x	x
Hydrostatic Testing Fluid	x			x	x	x		x	x
Cooling Water	x			x		x		x	
Deck Drainage	x			x	x	x		x	x
Bilge Water	x			x		x		x	
Sanitary and Domestic Waste Water	x			x					
Garbage									
Atmospheric Emissions	x								
Ships and Boats								x	
Helicopters								x	
Noise									
Drilling Rigs								x	x
Support Vessels								x	x
Helicopters								x	

Valued Environmental Component: Fish and Fish Habitat									
	Habitat			**Feeding**		**Reproduction**		**Adult Stage**	
	Water Quality	**Sediment**	**Topography**	**Plankton**	**Benthos**	**Eggs/Larvae**	**Juveniles**	**Pelagic Fish**	**Groundfish**
Shore Facilities[a]	N/A*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
B. PRODUCTION PHASE									
Presence of Structures									
No Fishing Zone					x		x	x	x
Artificial Reef Effect					x		x	x	x
Subsea Structures			x		x				
Surface Structures								x	
Lights and Flares				x		x	x	x	
Underwater Maintenance	x	x			x		x	x	x
Injection Water	x			x		x	x		
Produced Water	x			x	x	x	x	x	
Subsea Control Valves	x	x		x	x		x	x	x
Cooling Water	x			x		x			
Deck Drainage	x			x		x			
Sanitary and Domestic Waste	x			x					
Garbage									
Atmospheric Emissions	x								
Ships and Boats								x	x
Helicopters								x	
Noise									
FPSO								**x**	**x**
Support Vessels								x	x
Helicopters								x	
Shore Facilities[a]									
Offshore Oil Spills[b]									
C. DECOMMISSIONING PHASE									
Offshore									
Decommissioning				x	x	x	x	x	x
Abandonment									
Onshore[a]	N/A*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Valued Environmental Component: Fish and Fish Habitat									
	Habitat			Feeding		Reproduction		Adult Stage	
	Water Quality	Sediment	Topography	Plankton	Benthos	Eggs/Larvae	Juveniles	Pelagic Fish	Groundfish
D. OTHER PROJECTS AND ACTIVITIES									
Hibernia	x	x	x	x	x	x	x	x	x
Terra Nova	x	x	x	x	x	x	x	x	x
Exploration	x	x	x	x	x	x	x	x	x
Fisheries	x	x		x	x		x	x	x
Marine Transportation	x			x				x	

* Not applicable
[a] There will not be any new onshore facilities. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

Table 4.3-2 Environmental Effects Assessment on Fish and Fish Habitat – Development Phase

Valued Environmental Component: Fish and Fish Habitat
Phase: Development to First Oil

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
DEVELOPMENT PHASE			**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/Socio-Cultural and Economic Context**
Presence of Structures								
No Fishing Zone	Safe Refuge From Fishing (P)		1	3	6	3	R	1
Artificial Reef Effect	Increased Food and Shelter (P)		1	2	6	3	R	1
Subsea Structures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lights and Flares	Attraction (A)		0	1	6	3	R	1
Underwater Construction	Benthic Food Supply (A)	No Blasting	0	1	1	3	R	1
Drilling Mud/Cuttings								
Water-Based Mud	Contamination (A); Habitat Alteration	Recycle; Treat muds and discharge cuttings	0	1	2	3	R	1
Synthetic-Based Mud	Contamination (A); Habitat Alteration	Recycle; Treat muds and discharge cuttings	0	1	2	3	R	1
Other Fluids and Solids								
Completion, Packer and Workover	Contamination (A)	Recycle	0	1	2	3	R	1
Cement	Negligible		0	1	1	3	R	1
BOP Fluid	Contamination (A)	Recycle	0	1	2	3	R	1
Hydrostatic Testing Fluid	Contamination (A)		0	1	1	1	R	1
Cooling Water	Growth (P); Shock (A)		0	1	6	3	R	1
Deck Drainage	Contamination (A)	Treatment	1	1	2	3	R	1
Bilge Water	Contamination (A)	Treatment	0	1	2	3	R	1
Sanitary and Domestic Wastes	Nutrients (P); Contamination (A)	Treatment	0	1	6	3	R	1
Garbage	No interaction	N/A						
Atmospheric Emissions	Water Quality (A)	Equipment Design	0	2	6	3	R	1
Ships and Boats	Disturbance (A)		0	1	4	3	R	1
Helicopters	Disturbance (A)		0	1	5	3	R	1
Noise								
Drilling Rigs	Disturbance (A)		0	2	6	3	R	1
Support Vessels	Disturbance (A)		0	2	6	3	R	1
Helicopters	Disturbance (A)		0	1	5	3	R	1

Valued Environmental Component: Fish and Fish Habitat
Phase: Development to First Oil

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects					
DEVELOPMENT PHASE			**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/Socio-Cultural and Economic Context**
Shore Facilities [a]	N/A	N/A						

KEY

Magnitude:
0 = Negligible, essentially no effect.
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility:
R = Reversible
I = Irreversible
(refers to population)

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

N/A = Not Applicable

[a] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.

Table 4.3-3 Significance of Predicted Residual Environmental Effects on Fish and Fish Habitat - Development Phase

Valued Environmental Component: Fish and Fish Habitat				
PHASE – DEVELOPMENT	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Presence of Structures				
No Fishing Zone	P	3	3	3
Artificial Reef Effect	P	3	3	3
Subsea Structures	P	3	3	3
Lights and Flares	NS	3	3	3
Underwater Construction	NS	3	3	2
Drilling Mud/Cuttings				
Water-Based Mud	NS	2	3	2
Synthetic-Based Mud	NS	2	3	2
Other Fluids and Solids				
Completion, Packer and Workover	NS	3	3	3
Cement	NS	3	3	2
BOP Fluid	NS	3	3	3
Hydrostatic Testing Fluid	NS	3	3	3
Cooling Water	NS	3	3	3
Deck Drainage	NS	3	3	3
Bilge Water	NS	3	3	3
Sanitary and Domestic Wastes	NS	3	3	3
Garbage				
Atmospheric Emissions	NS	3	3	3
Ships and Boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
Drilling Rigs	NS	3	3	3
Support Vessels	NS	3	3	3
Helicopters	NS	3	1	3
Shore Facilities[a]				
Accidents[b]	NS	2	1	3

Key:

Residual environmental Effect Rating:
S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) *and* geographic extent >100 km^2 (4 or greater rating).

Level of Confidence: based on professional judgement
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgement
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

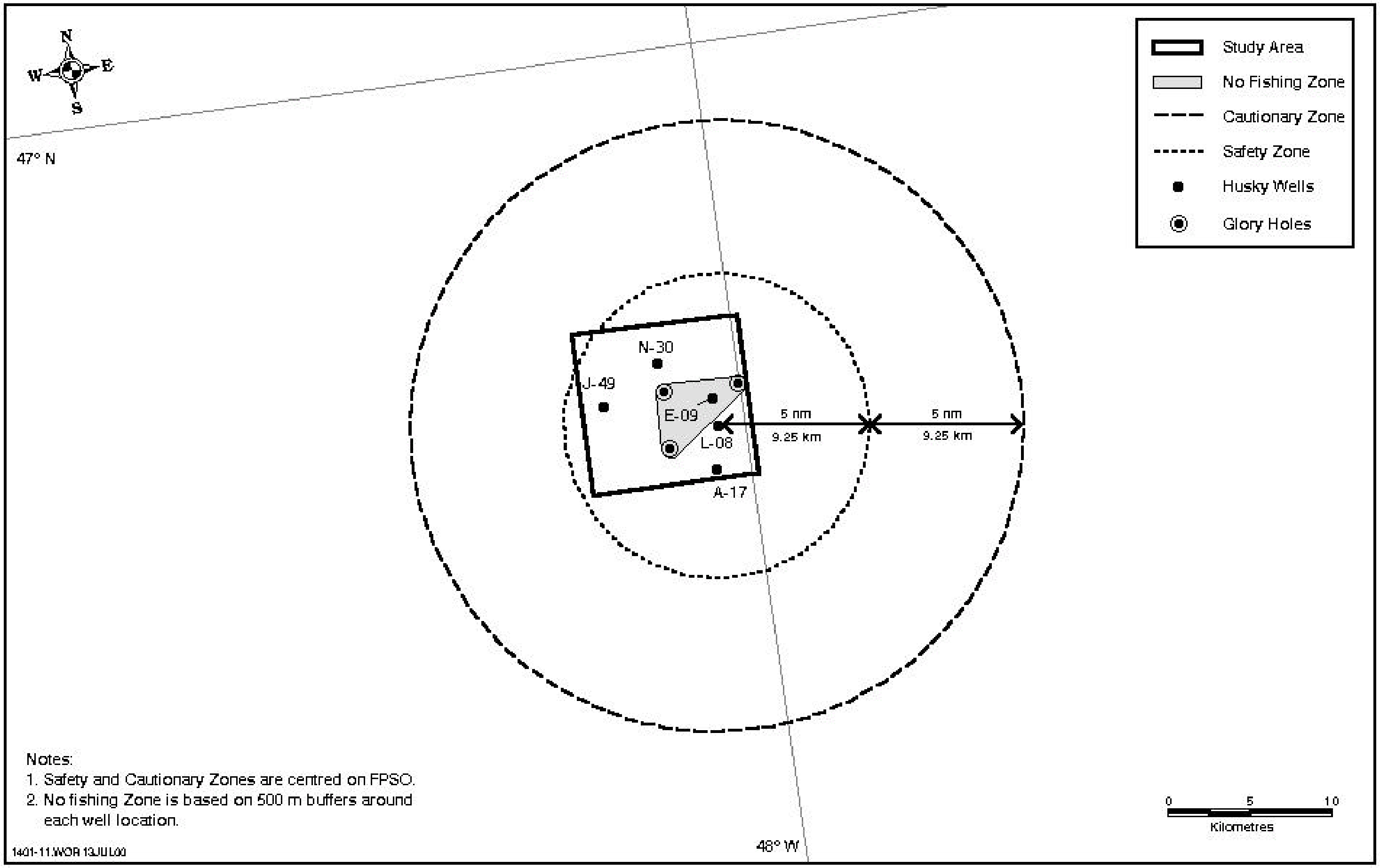
N/A = Not Applicable

[a] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

4.3.1.1 Presence of Structures

Structures will be protected by a Safety Zone and 'no fishing zone' (Figure 4.3-1). Subsea structures will consist of manifolds, christmas trees, and well heads, all protected from icebergs by glory holes.

Figure 4.3–1 White Rose Project Area: No Fishing Zone and Safety Zone



The subsea structures and associated safety zone have the potential to alter the local abundance and distribution of fish. The safety zone, encompassing a regulated (the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations*) 500 m buffer around each primary development well will be approximately 100 km^2 in total area. The actual no fishing zone will be approximately 15.4 km^2 (Figure 4.3-1). (Note, however, that one additional glory hole could be developed at White Rose if ancillary oil pools prove commercial, increasing the no fishing zone to 45 km^2).

The 15.4-km^2 closed area could create a refuge, where fish, including commercially important species, would be attracted to the subsea structures and become concentrated. Therefore, on fish populations, the reef effect and the no fishing zone acting together at White Rose could have a positive, continuous, low magnitude and local geographic extent. This refuge and enhancement of local populations, which could move outside the development area, may somewhat offset the negative effect of the no fishing safety zone on fisheries (see Part Two). These effects on fish and fish habitat are not significant (Table 4.3-3).

Hibernia has a no fishing zone of 5.2 km^2 and Terra Nova will have one of approximately 13.8 km^2, both containing subsea structures. The cumulative effects on fish and fish habitat will be additive, but are judged not large enough to change the overall effects rating.

Effects on Benthic Animals

The presence of structures can modify the characteristics of the adjacent seabed substrates and associated infaunal communities (Davis et al. 1982) (such as, fish habitat). Changes in benthic communities are also related to increased predation by fish, such as cod, which are attracted to the structures, and by invertebrate predators, such as starfish, which are attracted to the area by the presence of epifaunal prey (Davis et al. 1982). Scavengers are attracted to the area by the presence of removed fouling organisms on the bottom (Dicks 1982).

There has been much concern over the long-term effects of trawling on the benthos. Some studies have shown effects and some have not (Messieh et al. 1991). Some authors have concluded that extensive trawling can produce long-term changes in sediment characteristics and the structure of the benthic community (deGroot 1984). The Bedford Institute of Oceanography (BIO) and the Northwest Atlantic Fisheries Centre, St. John's have conducted a collaborative research project for approximately 10 years on the effects of trawling on the Grand Banks. The research was conducted in an area about 75 km northeast of Hibernia, near White Rose, that has been closed to trawling since 1987 (see Section 3.4.2.3 for further discussion). The White Rose no fishing zone will allow recovery of the benthos in the zone, and could provide valuable comparative data for that study.

Effects of the presence of structures on benthos would depend on the state of the fisheries. If the cod fishery does not recover, and present low levels of fishing are maintained, then the relative effects of a fishery closure on the benthos are likely to be *negligible*. On the other hand, if the fishery recovers, then the relative effects of a no fishing zone on the benthos are quite likely to be *positive*, *low magnitude (affects less* *than 10 percent of individuals), continuous* and *not geographically extensive (11-100 km^2)* (see Table 4.3-2). In any event, the effects on benthic animals are *not significant* (Table 4.3-3).

Hibernia has a no fishing zone of 5.2 km^2 and Terra Nova will have one of approximately 13.8 km^2, both containing subsea structures. The cumulative effects on benthos will be additive and positive, but are not judged large enough to change the overall effects rating.

Biofouling

The subsea structures will create habitat for biofouling organisms (benthic epiflora and fauna). In the North Sea, most of the fouling biomass in the upper 50 m is composed of seaweeds, hydroids, mussels, soft corals and anemones. Below that depth, hydroids, soft corals, anemones and tubeworms are the most common animals (Welaptega 1993).

Colonization of subsea structures by fouling epifaunal animals and plants is considered a nuisance and eventually a hazard (that is, an effect of the environment on the project). Epifaunal animals make visual inspections more difficult, increase hydrodynamic loading, contribute to fatigue and corrosion, and may interfere with corrosion protection systems (Edyvean et al. 1985). Biofouling could cause *low* to *medium magnitude, continuous, negative effects in a very small geographic area* (Table 4.3-2). This effect of the environment on the project is *not significant*.

Fouling organisms may be periodically removed as necessary using diver- or ROV-deployed brushes or high-pressure water jets (Welaptega 1993). Removal of fouling organisms will reduce effects to *negligible*. The accumulation of removed fouling organisms on the bottom may further attract invertebrate and fish predators (Dicks 1982).

Cumulative effects with other developments on the Grand Banks can be considered *negligible*.

4.3.1.2 Lights and Flares

The drilling rigs and supply and standby ships will carry navigation lights and warning lights. Working areas will be illuminated with floodlights. The helicopter pads on the drilling units and the FPSO will be floodlit and have landing lights visible 360°. Drill rigs may conduct flaring.

Fish and squid may be attracted to illuminated surface waters near the vessels (Hurley 1980), however, the effects on fish and squid would be *negligible* because numbers and areas affected are very small and the effect will not increase mortality to any noticeable degree. There would also be a *negligible* effect at the other developments, with an overall *negligible* cumulative effect.

4.3.1.3 Installation of Seabed Components and Underwater Construction

Glory holes will probably be excavated using a trailing suction hopper dredge or other acceptable excavation technology. The glory holes will be up to 11 m deep and provide a minimum clearance of 2 to 3 m below seabed. Husky Oil is also investigating single-well iceberg protection for satellite wells as well as single-well glory holes. Flow lines will connect the glory holes to the marine riser and FPSO; they are expected to be trenched to a depth of 2 m. Currently it is anticipated that three to four glory holes will be required. Two of these will be double (containing two templates with up to five wells per template). The third glory hole will be a triple (three templates; up to five wells per template). If a fourth glory hole is required, it will be a double glory hole. Double glory holes are 45 m long; 25 m wide and 11 m deep requiring excavation of approximately 54,000 m^3 of material. The triple glory hole is 25 m wide and 11 m deep but is 65 m long, requiring excavation of approximately 67,000 m^3 of material. The 2-m deep flowlines will require excavation of approximately 271,000 m^3 of material. Total excavation volume required under this scenario (three doubles, one triple) is estimated at approximately 500,000 m^3. The excavated material is brought up onto a barge, which, when fully loaded, moves off site and discharges it into the ocean. The excavated materials will be deposited as close to the excavated site as is operationally feasible.

Benthic habitat will be disturbed during construction of the glory holes and trenching of the flowlines; however, recolonization occurs rapidly once the disturbance ends. Quantification of altered, disturbed or destroyed habitat is required by DFO as per its Policy for the Management of Fish Habitat, as is development of a fish habitat compensation plan.

Fish Habitat Compensation Strategy

DFO's Policy for the Management of Fish Habitat states that if it proves impossible or impractical to maintain the same level of habitat productive capacity through redesign or relocation of infrastructure, DFO will explore compensatory options as mitigation (DFO 1986). DFO, as stated in the scoping document has determined that the White Rose project will result in the harmful alteration, disruption or destruction of fish habitat and thereby require a Section 35(2) *Fisheries Act* Authorization for works and Undertakings Affecting Fish Habitat. DFO also states in the scoping document that as a condition of that authorization, Husky Oil will be required to develop a fish habitat compensation plan that will form the basis of a legally binding compensation agreement between DFO and Husky Oil.

The first step in developing a fish habitat compensation agreement is quantifying the altered, disturbed or destroyed habitat. Based on the precedent set on the Terra Nova Project that the construction of the glory holes and the presence of flowlines resulted in altered, disrupted or destroyed fish habitat, Husky Oil has undertaken a quantification to calculate habitat disturbed or smothered by the construction of glory holes and presence of the flowlines. Husky Oil has estimated up to 145,500 m^2 of area could be disturbed by glory hole construction and flowline laying.

Husky Oil's strategy for compensation for those units will follow the DFO hierarchy of preferred compensation options (DFO) 1995):

- create similar habitat at or near the development site within the same ecological unit;
- create similar habitat in a different ecological unit that supports the same stock or species;
- increase the productive capacity of existing habitat at or near the development site and within the same ecological unit;
- increase the productive capacity of a different ecological unit that supports the same stock or species; and
- increase the productive capacity of existing habitat for a different stock or a different species of fish either on or off site.

The previous habitat description exercises specific to the White Rose site (Section 3.4.2) combined with the results of the White Rose Baseline Characterization Survey (Husky Oil 2000c) will provide key information that will be used to provide a detailed habitat compensation plan for review by DFO.

Husky Oil's strategy for habitat compensation using the DFO hierarchy of preferred options will include a review of the following options:

- opportunities to enhance productive fish habitat at site;
- opportunities to collaborate with other operators who may be enhancing fish habitat off-site; and
- opportunities to enhance habitat specific to those species found at the White Rose site at some other location.

Husky Oil commits to developing a fish habitat compensation plan that will be sufficiently detailed to form the basis of the required legally binding Compensation Agreement. As per the DFO policy, the compensation plan will require Husky Oil to conduct follow-up monitoring to determine the effectiveness of the compensation measures.
No underwater blasting is anticipated. Disturbance will occur over relatively small areas. Recolonization by opportunistic species can be quite rapid, even in cold water (Thomson and Martin 1984), therefore, effects on the benthos are likely to be *negligible*.

The underwater construction may temporarily displace fish by approximately 100 m but these effects would be *negligible*. This would be a *negligible* effect at the other developments as well with an overall *negligible* cumulative effect on fish and fish habitat.

4.3.1.4 Discharge of Drilling Muds and Cuttings

All development drilling within the White Rose area will be conducted using either water-based drilling muds (WBM) or synthetic-based muds (SBM). Plans are to drill primarily with WBMs, however, SMBs would be used in difficult or highly deviated situations and may also be needed in the reservoir section to avoid formation damage. All drilling fluids will be handled and treated in accordance with C-NOPB policies and Offshore Waste Treatment Guidelines (OWTG) (NEB, C-NOBP and C-NSOPB 1996).

Drilling muds are needed to convey the drill cuttings out of the hole and to keep formation fluids from entering the well. During the drilling of the top hole sections, the riser is not in place and drilling mud and cuttings (or sediments) from the top part of the hole are discharged from the hole to the seabed. After installation of the first two casing strings, the Blow Out Preventer (BOP) and riser provide a conduit from the seabed to the rig that takes the drilling mud and cuttings back to the surface mud system. Once on board the rig, the drill cuttings are removed from the mud in successive separation stages and discharged.

Some mud remains with the discharged cuttings. At several stages during drilling and at the end of the drilling process, WBM is discharged over the side. In the case of SBM all the whole mud is shipped back to the shore base. The SBM associated with the drill cuttings will be handled and treated in accordance with C-NOPB policies and the current OWTG (NEB, C-NOPB and C-NSOPB 1996) as noted above.

The main component of WBM is either fresh water or seawater. The primary WBM additives include bentonite (clay) and barite. Other chemicals such as potassium chloride, caustic soda, soda ash, viscosifiers, filtration-control additives and shale inhibitors are added to control mud properties. Low toxicity chemicals are used for the water-based drilling mud to reduce the effect on the environment.

The main component of SBM is a non-toxic synthetic hydrocarbon fluid. The products used in synthetic-base systems include emulsifiers, wetting agents, filtration-control additives, viscosifiers, and thinners. Additional chemicals, such as lime and calcium chloride are added to control alkalinity and water phase activity, respectfully. The chemicals used in synthetic based systems are selected carefully for their performance characteristics and to reduce impact to the environment. SBM is not discharged over the side: it is shipped to the shore base for additional treatment for re-use or disposal.

The mud components and discharge volumes of WBMs cuttings and SBMs cuttings for typical well lengths being considered on White Rose are summarized in Tables 4.3-4 and 4.3-5, respectively. In addition, a comparison between WBM and SBM components and discharge volumes for the intermediate and reservoir sections is given in Table 4.3-6.

Some drilling fluids and their constituents that are presently in common use are shown in Table 4.3-7. It should be noted that the toxicities listed for the pure formulas are much higher than they would be for the complete formulations because they are tested at a higher concentration than they would appear in the fluid mix. Presently, Husky Oil is planning to use sea water gel and KCL polymer for WBM and IPAR-3 for SBM (F. Mackin, pers. comm.).

Table 4.3-4 Mud Components and Cuttings Discharge Volume for a Typical WBM System

Section	Unit mm	Scenario 1				Scenario 2				Scenario 3			
		914	406	311	216	914	406	311	216	914	406	311	216
DF System		Gel/SW	Gel/SW	WBM	WBM	Gel/SW	Gel/SW	WBM	WBM	Gel/SW	Gel/SW	WBM	WBM
Depth	Metre (brt)	250	900	2,800	5,500	250	900	3,200	6,000	250	900	3,400	6,460
Volume Usage	m^3	200	444	693	500	200	444	768	530	200	444	806	559
Wash Out	%	50	30	10	10	50	30	10	10	50	30	10	10
Products													
Barite	MT		39	96			39	106			39	111	
Bentonite	MT	22	43			22	43			22	43		
Calcium Carbonate	kg				51,515				54,519				57,544
Caustic Soda	kg	162	321	198	143	162	321	220	151	162	321	230	160
Fluid Loss Agent	kg			1,982				2,197				2,304	
Fluid Loss Agent	kg				5,724				6,058				6,394
Inhibitor	kg			3,963				4,394				4,609	
Fluid Loss Agent	kg			7,927				8,787				9,218	
Lubricant	L								10,595				13,978
Potassium Chloride	kg			83,231	57,239			92,268	60,577			96,787	63,938
Lime	kg	162	321			162	321			162	321		
Glycol – Inhibitor	L			20,796				23,054				24,183	
Soda Ash	kg	162	321	198	143	162	321	220	151	162	321	230	160
Viscosifier	kg				2,146				2,272				2,398
Viscosifier	kg			2,973				3,295				3,457	
Biocide	kg			59	50			66	53			69	56
Drilled Cuttings	kg	268,845	284,914	413,081	282,625	268845	284914	500,045	293,093	268,845	284,914	543,527	320,309
Volume of Cuttings	m^3	103	110	159	109	103	110	192	113	103	110	209	123

Note:
* Three scenarios were taken into account. Top hole sections remained the same depth with each scenario.
* The 311 mm and 216 mm increased in depth with each additional scenario.
* 914 mm & 406 mm hole sections - near seabed discharge.
* Only primary products were used. No ancillary products or completion chemicals were included in consumption.
* WBM used for complete well.

Table 4.3-5 Mud Components and Cuttings Discharge Volume for a Typical SBM System

Section	Unit	Scenario 1				Scenario 2				Scenario 3			
	mm	914	406	311	216	914	406	311	216	914	406	311	216
DF System		Gel/SW	Gel/SW	SBM	SBM	Gel/SW	Gel/SW	SBM	SBM	Gel/SW	Gel/SW	SBM	SBM
Depth	Meter (brt)	250	900	2,800	5,500	250	900	3,200	6,000	250	900	3,400	6,460
Volume Usage	m^3	201	450	431	396	201	450	499	420	201	450	533	443
Wash Out	%	50	30	7	5	50	30	7	5	50	30	7	5
Products													
Barite	MT	0	38	109	17	0	38	126	18	0	38	134	19
Bentonite	MT	21	42			21	42			21	42		
Calcium Carbonate	kg												
Calcium Chloride	kg			28,466	26,150			32,938	27,717			35,162	29,238
Caustic	kg	189	379			189	379			189	379		
Thinner	L			624	624			624	624			624	624
Emulsifier	L			756	8,736			864	9,360			918	9,776
Lubricant	L			0	4,368			0	4,784			3,120	4,992
Fluid Loss Agent	kg			4,750	3,500			2,200	3,700			2,350	3,900
Base Oil	L			309,000	284,000			357,000	301,000			381,000	317,000
Lime	kg	189	379	3,800	3,500	189	379	4,400	3,700	189	379	4,700	3,900
Soda Ash	kg	189	379			189	379			189	379		
Viscosifier	kg			8,558	8,717			9,897	9,250			10,556	9,761
Oil Wetting Agent	L			1,040	1,040			1,248	1,040			1,248	1,040
Drilled Cuttings	kg	268,731	285,042	401,609	270,150	268,731	285,042	486,158	280,156	268,731	285,042	528,432	306,170
Volume of Cuttings	m^3	103	110	154	104	103	110	187	108	103	110	203	118
Oil on Cuttings	kg			40,161	27,015			48,616	28,016			52,843	30,617

Note:
* Three scenarios were taken into account. Top hole sections remained the same depth with each scenario.
* The 311 mm and 216 mm increased in depth with each additional scenario.
* 914 mm and 406 mm hole sections - near seabed discharge.
* Only primary products were used. No ancillary products or completion chemicals were included in consumption.
* SBM was used **"only"** for 311 mm and 216 mm sections.
* Barite used for 311 mm and 216 mm section. Based on formation damage study, barite may be replaced with calcium carbonate.
* The SBM whole mud would be returned to shore base for additional treating and re-use or disposal.

Table 4.3-6 Mud Components, Cuttings Discharge Volumes, and Oil on Cuttings Comparison for WBM and SBM

DF System	WBM		SBM	
Section (mm)	311	216	311	216
Depth (m, brt)	3,600	6,000	3,600	6,000
Volume Usage (bbl)	5,306	3,294	3,643	2,639
Washout (percent)	10	10	10	8
Components				
Barite (MT)	116		146	18
Bentonite (MT)				
Calcium Carbonate (kg)		53,897		
Calcium Chloride (kg)			38,238	27,715
Caustic (kg)	150			
Defloc (L) Thinner			832	624
Dispac SL (kg) Polyanionic cellulose	2,412			
Emul HT (L) Emulsifier			1,008	9,360
Dualfo (kg) Modified Starch		5,989		
Partially Hydrolysed Polyacrylamide	4,824			
Idflo LT (kg) Starch	9,648			
Idlube XL (L)Lubricant		15,711	4,576	4,784
Interdrill S (kg) Fluid Loss Reducers			2,550	3,700
IA-35 (L) Base Oil			415,000	301,000
Potassium Chloride (kg)	101,305	59,886		
Lime (kg)		5,350	5,100	3,700
Staplex 500 (L) glycol	25,312			
Soda Ash (kg)	241	150		
Xanvis (kg) Xanthanum Gum		2,246		
XCD Polymer (kg)	3,618			
Truvis (kg) Viscosifier			11,475	9,250
Xcide 207 (L) biocide	72	52		
Oil Wetting Agent (L)			1,456	1,040
Drilled Cuttings (kg)	587,010	251,222	586,708	24,6995
Volume of Cuttings (m^3)	226	97	226	95
Oil on Cuttings (kg)			58,671	24,699
Source: Scenario 4 (2/26/00) by A. Dickson, MI Drilling Fluids.				

Table 4.3-7 Some Common Drilling Fluids, Ingredients, Purpose and Toxicity

Trade Name	Common Name	Ingredients	Purpose	Acute Aquatic Toxicity
M-I BAR	Barium sulfate	Barite (91-93 percent) Silica, crystalline, quartz (4-6 percent) Mica (1-5 percent)	Oil well drilling fluid additive. Weighting agent.	Passes mysid shrimp toxicity test required by U.S. EPA.
M-I GEL	Bentonite	Gypsum (1 percent) Silica, crytalline, quartz (2-15 percent) Silica, crystalline, Cristobalite (2-12 percent) Silica, crystalline, Tridymite (1-5 percent) Bentonite (70-95 percent)	Oil well drilling fluid additive. Viscosifier.	Passes mysid shrimp toxicity test required by U.S. EPA.
PULPRO (ALL GRADES)	Limestone	Silica, crytalline, quartz (1-5 percent) Calcium carbonate (95-100 percent)	Oil well drilling fluid additive. Bridging and weighting agent.	No data available.
CALCIUM CHLORIDE	Calcium chloride	Calcium chloride (60-100 percent)	Oil well drilling fluid additive. Oil well completion fluid additive. Weighting agent.	
CAUSTIC SODA (NaOH)	Sodium hydroxide	Sodium hydroxide (100 percent)	Oil well drilling fluid additive. pH modifier.	LC_{50}, 96 hrs, Fish: 125 mg/l EC_{50}, 48 hrs, Daphnia: 100 mg/l Passes mysid shrimp toxicity test required by U.S. EPA.
INTERDRILL Defloc		Dodecycbenzenesulfonic acid, Calcium salt (30-60 percent) Solvent naptha (petroleum), light arom. (12-40 percent) Aliphatic amine derivatives (10-30 percent) Butan-1-ol (10-30 percent) Naphthalene (0.5-1.5 percent)	Thinner.	No data on product as a whole. LC_{50}, 96 hrs, Fish for Butan-1-ol: 1,910 mg/l.
INTERDRILL EMUL HT		Hydrotreated light petroleum distillates (20-30 percent) Aliphatic alcohol glycol ether (8-18 percent) Aliphatic amide (60-70 percent)	Emulsifier.	No toxicity data available. Partially biodegradable.
DEHYLUB 1036		Fatty derivative	Base Oil	No toxicity data available.
INTERDRILL S	Gilsonite	Gilsonite (100 percent)	Oil well drilling fluid additive. Fluid loss reducer.	
IA-35 IPAR3	Base Oil	Hydrotreated light petroleum distillates (60-100 percent)	Base oil	LC_{50} 96 h mysid shrimp >500,000 ppm LC_{50} 96 hRainbow trout >400,000 ppm Microtox™ Test Pass Sheen Test Pass
LIME	Lime	Calcium hydroxide (100 percent)	Oil well drilling fluid additive. Calcium source.	
SODA ASH	Sodium carbonate	Sodium carbonate (100 percent)	Oil well drilling fluid additive. Calcium precipitation.	Passes mysid shrimp toxicity test required by U.S. EPA.
TRUVIS	Organophilic clay	Aromatic amine treated mineral (60-100 percent) Crystalline silica (0.1-1.0 percent)	Viscosifier.	No toxicity data available.
INTERDRILL OW (Oil Wetting Agent)	-Quaternary Ammonium Detergent	Aromatic acid derivative (10-30 percent) Aliphatic alcohol (13.3 percent) Hydrocarbons (40-70 percent) Organic acids (5-10 percent) Aliphatic amine derivative (7-13 percent)	Wetting agent.	No toxicity data available.
Source: MSDS Sheets				

Terra Nova conducted a Life Cycle Value Assessment (LCVA) for the management of SBM and associated wastes (Pembina Institute n.d.). LCVA is a decision-making tool that combines environmental information for the full life cycle of a product or system with financial cost-benefit information. In the case of SBM use offshore, it enables a 'cradle to grave' approach and avoids simply shifting the environmental burden elsewhere. Using techniques consistent with the United States Department of Environment (DOE) and Environmental Protection Agency (EPA), three options were evaluated:

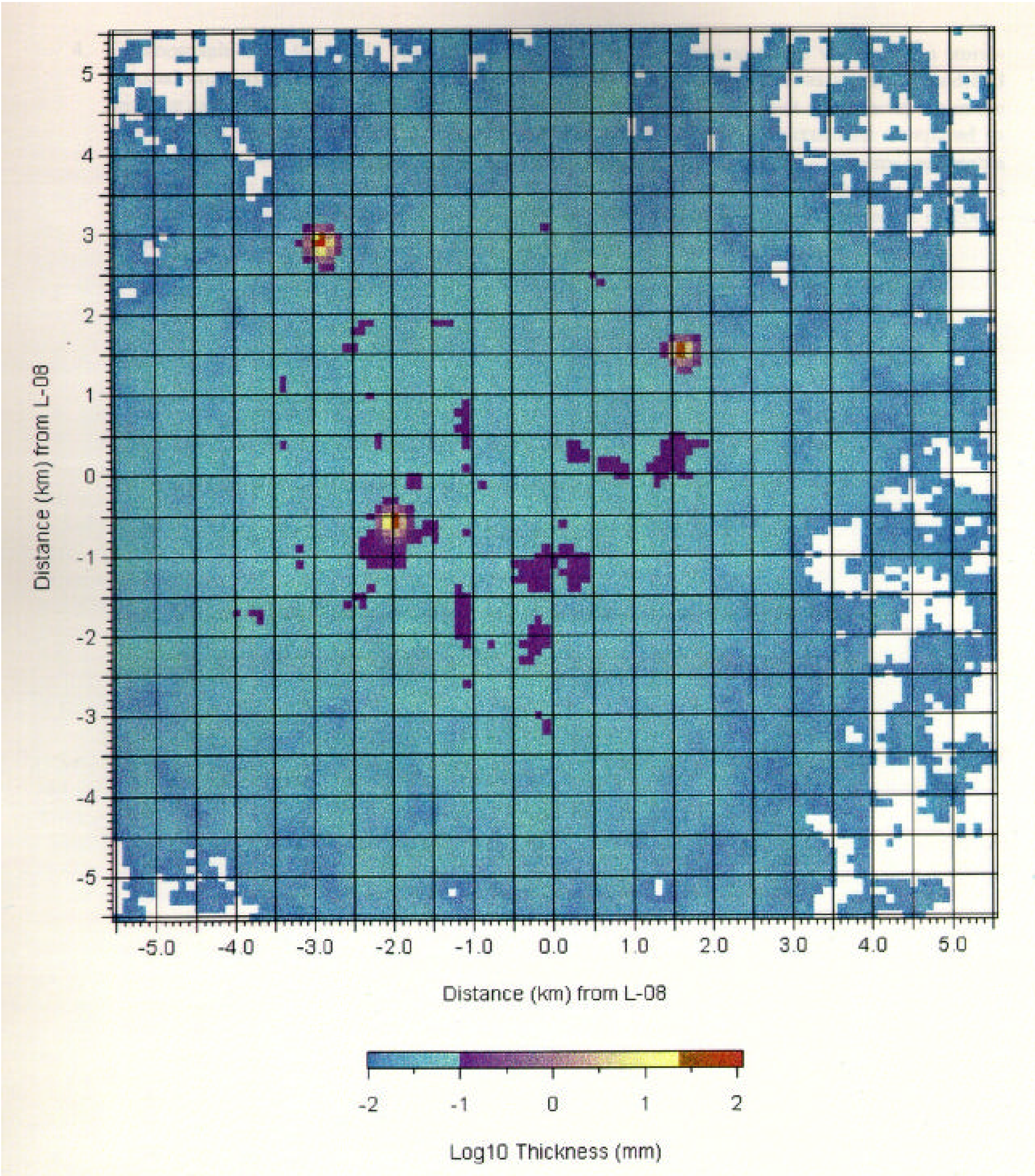
1. at-sea discharge of SBM cuttings and associated wastes,
2. re-injection; and
3. shore-based treatment.

Both environmental 'cost' factors such as greenhouse gases, habitat disruption, atmospheric emissions, and so forth and financial cost factors were evaluated. The study concluded that at-sea discharge of drill cuttings associated with SBMs is, by far, the preferred alternative from both an environmental and economic perspective. This conclusion was based on the study's main findings that:

1. whole SBMs are not discharged; operationally; the muds are recycled;
2. the literature indicates that the environmental effects of SBMs are comparable to WBM;
3. the only biological effect of at sea discharge of drill cuttings indicated by the literature is smothering of the benthic community by the cuttings piles;
4. transport to shore of cuttings increases greenhouse gases, SO_x and NO_x emissions;
5. transport to shore of cuttings results in waste management and disposal issues on land;
6. reinjection is technically feasible only in portions of the reservoir;
7. reinjection may require additional, dedicated wells and/or glory holes; and
8. ship to shore and reinjection result in environmental burden shifting (from marine to air and land) but not a reduction in environmental effects.

Given that ZOI trajectories at Terra Nova and White Rose are similar (see next section) and that shore disposal distances are slightly greater for White Rose, it is Husky Oil's view that an LCVA for White Rose SBM cuttings (in progress) will reach conclusions similar to those for Terra Nova. Consequently, Husky Oil proposes to discharge SBM cuttings from its White Rose wells and has modelled the potential effect of that discharge to determine the nature and extent of the zone of influence. Modelling was conducted using the volumes shown in Scenario 3 in Table 4.3-5. Results of this modelling exercise are discussed in the following section (Zone of Influence at White Rose) and shown graphically in Figure 4.3-2.

Figure 4.3–2 Close-up Deposition Pattern for Drill Cuttings Thicknesses Exceeding 10 microns After Completion of all 25 Wells



(Hodgins and Hodgins 2000)

Zone of Influence at White Rose

ZOI can be defined by chemical and/or biological "markers". The boundary of the zone is defined by the points at which the measured variables reach background levels. Chemical markers can include metal or hydrocarbon concentrations in sediments. The measurement of contaminants in sediments is difficult and results can vary widely depending upon the sampling and analysis techniques used and other factors. Many authors refer to the chemically-defined zone of influence as the "contaminated area". The term 'contaminated' in the present context simply means that measured values are above some previously determined background level. The chemical contamination (such as, elevated levels) may not have any biological significance unless the contaminants are bioavailable and at high enough levels to affect natural processes.

A ZOI as determined by biological markers is normally smaller than one determined by chemical ones. Biological markers can include changes in species composition, biomass, contaminant body burdens, histology, genetics and enzyme induction. A ZOI determined by biological effects monitoring is the one that is most relevant in determining environmental effects.

In the North Sea, cuttings contaminated with low-toxicity oil-based muds from five wells were discharged at one location and affected benthos only to a limited extent. Biological effects were noted only in the immediate vicinity of the platform and were comparatively weak at 250 m and undetectable 750 m from the platform. Aliphatic hydrocarbon distributions for one well and five wells together are shown in Addy et al. (1984).

At the Venture Field off Sable Island, concentrations of low-toxicity oil in sediments were three to four orders of magnitude higher than background levels within 200 m of the drilling site, and dropped to 10 times background levels within 200 to 1,500 m of the drilling site (Yunker and Drinnan 1987). Note that this area is shallow, sandy, and the sediments are very mobile. As such, these observations are probably not relevant to White Rose.

Data from approximately 380 single wells sites in the North Sea show that sediments are contaminated along the axis of the prevailing current, but to distances about 25 percent or less of those at multi-well sites (GESAMP 1993). The zone of biological effects would be about 250 to 500 m from a single drilling site (GESAMP 1993). Within this zone, benthic animals were affected only in the immediate vicinity of the platform and minimally affected at 250 m. Effects were undetectable at 750 m from the platform (Addy et al. 1984). It is possible that minor biological effects from single wells could be noted up to 1 km from a single well and oil could be present at distances of 1 to 8 km from the well, depending on prevailing currents (GESAMP 1993). However, as discussed below, in practice, effects may be undetectable.

Recent investigations in the Norwegian sector of the North Sea show the zone of biological effects could be much larger than those described above. Olsgård and Gray (1995) have shown that the zone of influence increases with time and that after six to nine years, effects were noted up to 6 km away from the platform.

The expansion of affected areas continued after cessation of discharge of cuttings contaminated with OBMs. The area of effects was only slightly smaller than the contaminated area. An analysis of benthos at 10 platforms showed that the zone of effects was not directly related to the amount of oil discharged with cuttings. For 10 platforms, the zone of effects ranged from < 1 to 6 km. Unfortunately, OlsgØrd and Gray (1995) do not identify the type of OBM used, nor do they identify the kinds of hydrocarbons found in the sediments. Relatively large volumes of diesel-based mud have been used in the North Sea. In any case, because White Rose will use SBMs rather than OBMs it is not valid to transfer conclusions on biological effects or biologically determined ZOI from the results of OBM studies to the White Rose project.

If spent mud and cuttings are discharged into the ocean, it is possible to determine a potential ZOI by reviewing the results of past monitoring programs and by computer modelling. Modelling of drill cuttings discharges for the Terra Nova Development suggests a ZOI of generally less than 500 m around drill centres, but irregular areas and patches could extend beyond that on the order of several km. The Hibernia monitoring program sampling 44 stations around the GBS has confirmed a ZOI to date for that project of less than 500 m (HMDC 2000).

A modelling study of potential deposition characteristics of drill cuttings produced by the White Rose Development was conducted by Seaconsult (Hodgins and Hodgins 2000). The study assumes 25 wells will be drilled using SBMs and WBMs. This is an estimate of the total number of wells at the high end of the range. In addition, the model uses the highest volume of cuttings (scenario 3 in Table 4.3-5).

Upon completion of the maximum number of 25 wells forecast for White Rose, the maximum size of the area where cuttings and associated material would be deposited on the sea floor has a diameter of approximately 18 km (Figure 4.3-2). The area has a circular pattern caused by the rotational nature of both the tidal currents and the strong wind-induced currents at this location. The coarse material (for example, pebbles and coarse sand) is deposited within about +/-300 m of the drill centres to a maximum thickness of approximately 50 to 75 mm at the northeast and southwest centres, and exceeding 100 mm only within 100 m of the northwest drill centre. The deposition pattern of fine material (nominal diameter less than 0.1 mm) merges from the three drill centres leading to a combined thickness of the order of 100 to 300 microns (0.1 to 0.3 mm) in the central part of the pattern. Roughly, the oil concentration in sediments in ppm (mg/kg) is one to two times the thickness in microns. Thus, over the vast majority of the deposition zone, the expected oil concentrations in the sediments are less than 100 to 200 ppm. Only close to the drill centres (+/-300 m) would concentrations increase to over 1,000 ppm (1,000 mg/kg).

In general, conclusions that can be drawn from the White Rose modelling of cuttings deposition is in agreement with the exercises that were conducted for both Hibernia and Terra Nova; namely that the biological ZOI will be confined to within about 500 m of the drilling area.

Biological Effects of Drilling Muds and Cuttings

Biological effects of muds and associated oiled cuttings can include toxicity, smothering, habitat alteration and tainting of bottom-dwelling organisms.

Four basic types of drilling muds have been used by the oil industry. Their toxicity is based on the chemical constituents of the mud and the fluid.

1. Diesel oil-based muds (OBM) are toxic and can cause severe effects, including measurable effects on benthos. Diesel-OBM is no longer in general use and will not be used at White Rose. They are discussed in this section because much of the previous literature on effects of drill cuttings and muds concerns oil-based muds.
2. Low toxicity oil-based muds are much less toxic than diesel-based muds because the aromatic content is reduced.
3. SBM use a non-toxic synthetic fluid.
4. WBM toxicity is related only to the chemical constituents of the mud and the cuttings.

The release of muds and cuttings constitutes an environmental concern. In shallow areas, mud and cuttings may settle on the seabed, which can affect benthic organisms in the vicinity of the drilling. Transport of these materials by currents, particularly during storms, may affect water and sediment quality over larger areas.

Discharge of drilling muds and cuttings can affect all types of marine life. Most studies have concentrated on effects on benthic animals. Benthic communities are relatively immobile and complex. Some species are pollution-tolerant, while some are very sensitive. Thus, pollution-induced changes can be readily observed in the benthos. This is not the case with mobile species that may be exposed for only a short period of time and cannot be followed for examination.

Benthic communities respond to pollution in a relatively predictable manner. Freshwater and marine benthic communities exposed to spills of crude and refined oils, drilling cuttings, organic enrichment or other pollutants often show the following series of responses (Rosenberg 1976; Mair et al. 1987; Sanders et al. 1990; Nalepa 1991; Teal et al. 1992; Kingston 1992; Rosenberg and Resh 1993):

1. When contamination is very severe all animals in the immediate vicinity may be killed. [In contrast, if contamination is light then changes in benthic community structure may be very subtle.]

2. Where contamination is severe to moderate, abundance, biomass and species diversity are initially much reduced because pollution-sensitive species die.

3. After ‘1’ or ‘2’ above, pollution-tolerant species may then show a rapid and dramatic increase in abundance and total abundance of animals may be higher than before contamination.

4. As contaminant levels decrease, the abundance of pollution-tolerant species declines and the area is re-colonized by drifting larvae and mobile species from outside the affected area.

5. The benthic community then goes through various stages of succession, similar to a forest recovering from a fire. The time required for recovery depends on the growth rate and reproductive potential of the animals and the potential for larval settlement from other areas.

The observed changes in benthic community structure are related to the relative sensitivities of the species that form the communities. Echinoderms, crustaceans, especially amphipods and some harpacticoid copepods, and scallops are very sensitive to toxic chemicals while polychaetes and nematodes are not particularly sensitive (Peterson et al. 1996). The greatest changes in benthic communities are observed when communities dominated by sensitive species are exposed to pollution from diesel and other oil-based muds.

Benthic communities on the Grand Banks will probably respond to the discharge of drilling muds and cuttings in the same manner as they do in other cold temperate seas and they will respond to pollution in a manner typical of benthic communities. Husky Oil's commitment to using WBM and SBM (low toxicity) mud systems and to recycling whole SBM muds will reduce the effects to benthic communities and other sensitive organisms.

Effects of Synthetic-Based Muds and Cuttings

The SBMs are high performance drilling fluids that were developed to provide the performance of diesel or mineral OBM, but which would provide reduced environmental effects. The lower toxicity of SBM versus OBM is achieved through the elimination of PAHs, faster biodegradability and lower bioaccumulation potential. SBMs use synthetic materials as the base fluid, such as the vegetable esters, poly alpha olefins, internal olefins, linear alpha olefins, synthetic paraffins, linear alkyl benzenes and others. Other oleaginous materials have also been developed for this purpose, such as the enhanced mineral oils and non-synthetic paraffins.

Most of the SBM in current use can easily pass the EPA 96-h LC_{50} criteria of 30,000 ppm (McKelvie and Ayers 1999). Test results with four types of SBMs on algae, mysids, copepods, mussels and amphipods, selected species of which occur at White Rose, range from 277 to 1,000,000 ppm (McKelvie and Ayers 1999).

The term 96 LC_{50} refers to a standard toxicity test conducted over a 96-h period. The LC_{50} value is expressed at that concentration where 50 percent of the test organisms die. The major WBM components typically have 96-h LC_{50}s for many fish and invertebrates that are in the 100,000 ppm (10 percent) range, although some species, such as filter feeding oysters, are more sensitive (Thomas et al. 1984).

The EPA has reviewed the effects of SBM and compared these to those of WBMs (EPA 1999). Water column effects of SBM are less than those of WBM because the components of SBM do not disperse and have very low solubility in water. Organic enrichment and oxygen depletion in the sediments are expected to be the dominant effects of SBM (EPA 1999). The potential for toxicity appears to vary among drilling fluid types, but is generally quite low. Initial effects are likely between 50 to 500 m from the drilling rig (ERT 1996; EPA 1999). These distances are smaller than those described for use of WBM (EPA 1999).

The EPA believes that the environmental effects of SBM discharge is more comparable to WBM than to OBM (EPA 1999). There are several major differences between the use of WBM and SBM (EPA 1999).

1. For an equal volume of hole drilled, the volume of WBM discharge is usually much greater than the volume of SBM discharge because SBM is recycled and not discharged. SBM has, however, a limitation on the amount of times it can be recycled, so it finally has to be disposed of on land.

2. SBM cuttings tend not to disperse in the water column nearly to the same extent as WBM cuttings because the particles are bound with the synthetic material. SBM cuttings tend to be composed of larger chunks than WBM cuttings and so these larger particles settle faster than the smaller WBM cuttings particles. SBM cuttings tend to be deposited over a smaller area than WBM cuttings.

3. SBM has the potential for greater toxicity and organic enrichment of the seabed/sediments than WBM.

A Petro-Canada review document (Kiceniuk 1999) on IA–35 Fluid, a SBM formulation, concluded the following**:**

1. Effects of SBM cuttings on organisms in the water column will be minimal (if any).

2. Alkanes from the IA-35 Fluid will be readily metabolized by sediment dwelling organisms.

3. Emulsifiers and IA-35 Fluid are expected to degrade which will reduce potential for effects on scallops.

4. There will be no effect on flatfish feeding in the area of the cuttings piles.

5. The only biological effect will be physical smothering by the cuttings piles.

6. Slurrification could provide increased opportunity for increased biodegradation.

7. Some compounds may become bioavailable but they will not create persistent metabolites. Therefore, high bioavailability coupled with high metabolism will result in disappearance of the compounds from the environment.

8. If bioaccumulation occurs, there are no known effects caused by any compounds in IA Fluid 35. Results from Hibernia show that there has been no bioaccumulation of material in American plaice. Depuration of IA-35 Fluid will likely occur in organisms where bioaccumulation has occurred.

9. None of the compounds found in IA-35 Fluid or emulsifiers result in tainting in organisms.

Effects of Water-Based Muds and Cuttings

WBMs are relatively non-toxic when compared to OBM. The mud components are mixed with water prior to use. The concentrations of the individual components of WBM approximate their 96-h LC_{50} values to rainbow trout.

There are four main concerns related to the discharge of water-based muds and cuttings:

1. near-field effects related to smothering of the benthos by the cuttings pile;

2. effects of particles suspended in the benthic boundary layer;

3. effects of the settled particles on the benthos and other animals at some distance from the source; and

4. heavy metal contamination.

Effects of the Cuttings Pile

WBM cuttings and mud are discharged over the side. The heavy particles will settle near the discharge site and can form a pile on the bottom. However an examination of three exploration well sites drilled with WBM in the Hibernia field revealed only slight accumulations of drilling materials (NORDCO 1983).

At the offshore Nova Scotia Venture and Thebaud sites, cuttings mounds have been measured 1 to 3.5 m thick at the discharge point and 1 mm thick at distances of 400 to 600 m (SOEP 1997). At these shallow sites, it is estimated that the cuttings will have been dispersed to below detectable levels within one year (SOEP 1997). Cuttings mounds were thinner, but more widely dispersed at deeper sites.

Dunstan et al. (1991) examined individual exploratory drill sites off the Florida Keys. They found no cuttings pile near two exploration wells drilled to over 2,000 m total depth (TD) in 20 m of water, 30 years previously. They did find pieces of cuttings in the sediment at each site. Coverage by living organisms was the same on the seabed and on an abandoned pipe, which was the only visible sign of drilling activity in these high depositional environments. Biological communities appeared typical for the areas. At another site, drilled to 3,464 m TD in 53 m of water seven years earlier, signs of drilling activity were limited to an area of less than 50 m in diameter, however, the biological community appeared unaffected and no visible evidence of cuttings or mud was found. At an exploration well drilled two years previously in 70 m of water to 3,200 m TD, Dunstan et al. (1991) found a 10 to 15 m diameter mound that was 2 m high and appeared to consist mainly of casing cement with some cuttings. The expected cuttings pile could not be found. Benthic communities appeared disturbed within a radius of 25 m around the mound. The only permanent alteration of the soft-bottom seabed occurred where a pile of cement had smothered benthos over a 15 m diameter area. However, all the debris created artificial reefs, which attracted fish and provided substrate for epifaunal animals. The authors concluded that with modern technology and anti-dumping regulations, exploration drilling could probably be accomplished without leaving a trace. Exploration drilling in shallow and/or dynamic environments may not produce long-lasting effects related to cuttings piles.

Effects of Dispersed Drilling Waste

Individual fine particles settle slowly. However, fine particles interact with seawater and organic matter and form flocs (Muschenheim and Milligan 1996). This increases settling velocity and serves to retain the discharged material near the discharge point and hinders dispersal (Muschenheim and Milligan 1996). Material that is deposited can be re-suspended and transported (Neff et al. 1989a). The accumulation of this material occurs within the benthic boundary layer, which is within a few metres of the sea bottom. Sampling to distances of 15 km around a drilling site in 34 m of water near Sable Island in September 1994, showed that, on certain occasions, drilling wastes were present in the benthic boundary layer at distances of up to 8 km from the drilling site (Muschenheim and Milligan 1996). These were not present during sampling conducted the following spring.

The concentrations of drilling fluids required to cause acute effects have been determined for many species of marine animals (for example, Neff 1988; Parrish and Duke 1990; Bowmer et al. 1996). Most acute toxicity thresholds for muds are higher than concentrations expected under field conditions (Boudreau 1998).

Accumulation of suspended drilling wastes in the benthic boundary layer can affect sensitive species such as scallops. Filter feeding scallops ingest this material and have been shown to be very sensitive to the presence of drilling wastes (Cranford and Gordon 1992; Cranford et al. 1999). Because of their sensitivity, scallops probably represent the worst case scenario for effects of the presence of drilling wastes in the benthic boundary layer.

Cranford and Gordon (1992) and Cranford et al. (1999) studied the long-term effects of suspended drilling wastes on scallops. The wastes were classed as slightly toxic (96-h LC_{50} of 1,000 to 10,000 ppm) or non-toxic (96-h LC_{50} > 10,000 ppm). Key results of their studies were:

- Exposure to 1 mg/L (=1 ppm) of used WBM and cuttings for 72 d in summer resulted in increased gonad growth in scallops. The upper limit for growth enhancement was 10 ppm; with increasing concentrations causing reduced absorption efficiency and increased respiratory energy loss.
- Exposure to bentonite alone caused mortality and negative growth at concentrations of 10 ppm and above and reductions in feeding activity at 2 ppm. In contrast, Boudreau (1998) estimated the no effects concentration as 2 ppm.
- Exposure to 0.5 ppm of barite caused complete cessation of gonad growth after 24 d exposure; chronic effects would occur at lower concentrations. In comparison, Boudreau (1998) estimated the no effects concentration at 0.1 ppm.
- There was no indication of chemical toxicity from 68 and 72-d exposure to 1 and 5 ppm of used WBM and cuttings.
- Mortality of scallops exposed to whole WBM can be expected at concentrations > 2 ppm after 30d exposure (P. Cranford, pers. comm.).
- Exposure to used OBM caused mortality at concentrations of 2 ppm after 11 d exposure; mortality declined to 0 at concentrations of 0.5 ppm; the base oil was implicated in the toxicity.

Boudreau (1998) concluded that discharge of water-based muds from isolated exploration wells in the high energy environment of Georges Bank would limit effects to the area under and adjacent to the rig and that there would be no significant effects on resource species. Drilling wastes are not expected to accumulate in the benthic boundary layer due to drilling on the Grand Banks, including White Rose, because of the greatly increased dispersion in deep water compared to shallow waters.

Effects of Settled Drilling Wastes

The effects on scallops reported for shallow water Nova Scotia represent the worst case scenario, because they are very sensitive to effects of muds. Scallops occur at White Rose in non-commercial quantities but the water depths are much greater. Studies conducted in the North Sea and elsewhere have examined effects on benthic communities in general. Available results show that discharges from platforms in open waters of greater than 20 m depth should result in no acute effects in the water column (Parrish and Duke 1990). Water-based muds may cause adverse effects on benthic organisms within a few hundred meters of the discharge (Parrish and Duke 1990; Boudreau 1998).

In the Gulf of Mexico, effects of WBM on the benthos were found at distances within 100 to 200 m of production platforms (Peterson et al. 1996). The observed differences in community structure appear to have been related to sediment toxicity, specifically the presence of heavy metals in sediments near the platforms. OBMs were not used at these production platforms and so the zone of effects was much smaller than the 2 to 6 km found by Olsgård and Gray (1995) around North Sea production platforms where OBM was used. Daan and Mulder (1996) found no detectable effects on benthic communities as close as 25 m to the platforms, two months and one year after WBM had been used at several single-well sites in the North Sea. For multiple wells drilled with WBM from a platform, they found detectable differences in benthic community structure out to 1,000 m from the platforms.

In the North Sea, cuttings from five wells discharged at one location contaminated with low-toxicity oil-based muds produced only limited effects on the benthos; biological effects were noted only in the immediate vicinity of the platform, were comparatively weak at 250 m and were undetectable at 750 m from the platform (Addy et al. 1984).

At the Venture field off Sable Island, concentrations of oil in sediments resulting from the discharge of cuttings drilled with low-toxicity oil were three to four orders of magnitude higher than background levels within 200 m of the drilling site and dropped to 10 times background levels within 200 to 1500+ m of the drilling site (Yunker and Drinnan 1987).

Data collected from over 380 sites where single wells were drilled with OBM in the North Sea indicate that contamination occurs along the axis of the prevailing current to distances of about one-quarter or less than those experienced at multi-well platforms (GESAMP 1993). The zone of biological effects would be about 250 to 500 m from a single drilling site (GESAMP 1993). Theoretically, minor biological effects from single wells could be noted up to 1 km from a single well and oil could be present at distances of 1 to 8 km from the well, depending on prevailing currents (GESAMP 1993).

Heavy Metal Contamination

The drilling muds and/or the cuttings can contain heavy metals. The kinds and quantities of metals released can be quite variable depending on the composition of the mud and the cuttings. In the Gulf of Mexico, contamination by heavy metals was limited to an area within 100 to 200 m of the production platforms (Wheeler et al. 1980; Peterson et al. 1996). However, Wheeler et al. (1980) believed that some trace elements that they found could have been deposited by produced water rather than by cuttings; the field had been in operation for 20 years at the time of sampling.

Computer modelling of dispersion of cuttings showed that treatment reduced maximum oil concentrations by up to 98 percent, frequently reduced oil concentrations to less than 1,000 ppm or drastically reduced the area where oil concentrations exceeded 1,000 ppm (Brandsma 1995). Experiments also showed that simulated drill cuttings without oil, but with barium (700 to 1,100 μg/g), cadmium (2 to 5 μg/g), lead (300 to 800 μg/g), and zinc (160 to 450 μg/g), had no short-term gross effects on community structure. Barite is not of great concern since it is insoluble and therefore, not bioavailable and chrome products are no longer used.

High concentrations of heavy metals can be toxic, bioaccumulate, bioconcentrate, and can have harmful effects on marine life (Forstner and Wittmann 1983). However, the uptake of metals by marine animals depends on the bio-availability of the metals. Bio-availability is generally low when metals are adsorbed onto particles or complexed with organic molecules (Forstner and Wittmann 1983; Leland and Kuwabara 1985; Hinwood et al. 1994). This generally happens in natural waters and total concentrations do not always reflect the availability of metals to animals (Forstner and Wittmann 1983). Heavy metals in drilling fluids are present in insoluble forms or are adsorbed on clay particles and have limited bio-availability (Neff 1988; Neff et al. 1988; 1989a; 1989b). Thus, drilling activities are unlikely to produce concentrations of heavy metals that are harmful to marine animals (Neff et al. 1980 in Hinwood et al. 1994).

Duration of Effects and Recovery of the Benthos

In areas of the North Sea, benthos on sediments initially contaminated with up to 4,300 ppm of diesel-based mud from multiple wells, partially recovered one to two years after drilling (Mair et al. 1987; GESAMP 1993). Opportunistic species colonized the substrates within a few months (Kingston 1992). North Sea data indicate biological effects and contamination from single wells may not last beyond one season of winter storms (GESAMP 1993).

Low-toxicity OBMs are biodegradable under aerobic conditions, but not under anaerobic conditions (Steber et al. 1995). In the upper centimetre of sediment, oil will biodegrade in approximately 150 days (Petersen et al. 1991), but oil within a pile of cuttings or at depths greater than 1 cm remains unchanged for long periods of time (Yunker and Drinnan 1987; Petersen et al. 1991; Steber et al. 1995). Yunker and Drinnan (1987) found decreasing concentrations of low-toxicity oil with increasing core depth, suggesting that at least part of the oil floated to the top of the cuttings pile. They found little or no oil biodegradation below the sediment surface. Wave action and weathering significantly reduced hydrocarbon content in the sediments near the drill site within three months.

Dunstan et al. (1991) examined seven individual exploratory drill sites off the Florida Keys ranging in age from 2 to 30 years. Dunstan et al. (1991) conclude that with modern technology and anti-dumping regulations, exploratory wells could probably be drilled without leaving a trace. They caution that these results cannot be extrapolated to the effects of production well groups. Similarly, examination of three exploratory well sites drilled with water-based muds in the Hibernia field revealed only slight accumulations of drilling materials (NORDCO 1983).

Current plans for White Rose, envisage the use of three to four glory holes and drill centres located several kilometres apart and containing up to 25 wells in total. This is different than production drilling at Hibernia or the North Sea, where many wells are drilled from a single platform and all cuttings are discharged in the same place. At each of the drill centres, the zone of influence and effects of drilling will be smaller than that around fixed production platforms and slightly larger than at single well sites. This was supported by Hodgson and Hodgson (2000).

Effects on Fish and Fish Habitat

Bioaccumulation of oil in tissue and subsequent tainting of fish flesh has been identified as a potential problem associated with the use of oil-based muds (GESAMP 1993). Tainting imparts an oily taste to fish, rendering them unpalatable and unmarketable. Tainting is usually associated with lipid-soluble hydrocarbons in the C_{22}-C_{30} range, with a maximum at C_{26} (Tidmarsh et al. 1986). Phenols, dibenzothiophenes, naphalenic acids, mercaptans, tetradecanes and methylated naphalenes may be the principal components causing tainting. As low-toxicity drilling muds contain highly refined paraffinic and naphthenic oils, there is a small potential for tainting by these components.

Flatfish near offshore platforms may become tainted if hydrocarbon concentrations in sediments exceed 200 ppm dry weight (S.L. Ross and LFA 1993). Although flatfish can bioaccumulate hydrocarbons from drill cuttings in their livers, it is unclear whether they would accumulate enough hydrocarbons in muscle tissue to cause tainting (S.L. Ross and LFA 1993). The authors suggested that cuttings discharged from platforms in deep water would lose the lighter fractions of oil, known to cause tainting, while falling through the water column.

Much of the literature on the effects of drilling muds may not be directly applicable to White Rose because it is based on the use of OBMs; low-toxicity muds (WBM and SBM) will be used at White Rose.

In the White Rose Development, low toxicity drilling muds will be used, recovered and recycled. The 48-h average concentration of oil in released cuttings will be 15 g/100 g dry cuttings or less. This amount is lower than that released by the fields discussed in previous sections. Some of the oil on discharged cuttings will dissolve while the cuttings pass though the water column. Oil that remains adhered to cuttings will aerobically degrade. Because only small numbers of wells will be drilled per year in the development area, the concentration of oil in sediments will remain low and will affect benthos in only a very limited area. Muds will be recovered and recycled. Spent mud will be shipped to shore for disposal. The components of water-based muds are relatively nontoxic. The effects of the discharge of WBM muds and cuttings are unlikely to persist beyond one storm season.

Petro-Canada commissioned a study to review chemicals to be used in the Terra Nova drilling program (Kiceniuk 1999). This study concluded that the use of synthetic fluid IA-35 Fluid, one of the fluids under consideration by Husky Oil (see Table 4.4-7), will not result in tainting of fish. Fish that may become tainted are likely to be those that are attracted to the subsea structures and reside in the no fishing zone. Highly mobile fish are unlikely to remain near oiled cuttings long enough to become tainted. The environmental effects monitoring program (EEM) (Chapter 7) will track fish tainting by all sources of hydrocarbons, including oiled cuttings that could be released during development. If tainted fish are found, the source of tainting will be investigated and further mitigation measures implemented.

Effects on benthic animals could be *low* to *high* in *magnitude* and *medium duration* within a few hundred metres of the drilling sites and *low magnitude* and *short duration* within one km^2. Overall, effects on the benthos are likely to be *low magnitude* and *short duration* with small areas experiencing *low* to *high magnitude effects* on benthic animals (Table 4.3-2). This results in a *not significant effect* on the fish and fish habitat VEC. A monitoring program will be implemented to determine the extent and duration of contamination of the sediments and the extent and duration of effects on benthic animals.

Only a few wells will be drilled each year from any given drilling location. Drilling will occur over a three to four year period. Effects on fish would be *negligible* and not significant, as would cumulative effects with the other developments.

Exploratory Drilling

To date there have been a total of 106 exploration, delineation, and production wells drilled on the North Grand Banks, a large region within which the Hibernia, Terra Nova and White Rose developments are located (C-NOPB 2000b). There are presently a total of 24 current exploration licences for the Grand Banks region, including those held by Husky Oil (C-NOPB 2000c). However, these numbers are not indicative of the number of exploration wells likely to be drilled during a typical year on the Grand Banks. The Canadian Association of Petroleum Producers (CAPP) has predicted that there will be between one and four drill rigs per year operating on the Grand Banks over the next 10 years (CAPP 1999). CAPP's scenario for a moderate level of activity predicts two rigs drilling exploration, delineation and production wells on the Grand Banks over the next ten years.

There will be a total of two exploration wells (Husky Oil et al. Cape Race N-68 and Petro-Canada et al. Riverhead N-18) completed during the Year 2000, a relatively active year (C-NOPB 2000d, 2000e; D. Burley, pers. comm.). It is reasonable to assume, on average, that there will be one or two exploratory wells drilled per year within North Grand Banks for the foreseeable future (CAPP 1999; D. Burley, pers. comm.). Predictions in this EIS are based upon one or two exploratory wells per year in addition to any delineation and production drilling. Any cumulative effects on the Grand Banks ecosystem from routine exploratory drilling outside the White Rose development area will probably not overlap and thus, will be additive to the activities of White Rose. This level of activity will not change the effects predictions when viewed on a cumulative basis unless significant oil spills or blowouts occur (see Section 5.7 for a summary of accidental events).

Mitigation

Mitigation measures for the White Rose Development include the use of low toxicity WMBs and SBMs, and treating oil-contaminated cuttings to meet the current OWTG (NEB, C-NOPB and C-NSOPB 1996).

4.3.1.5 Discharge of Other Fluids and Solids

Other fluids associated with the drilling and completion of wells include completion, packer and workover fluids; cement slurry; and BOP fluid.

Husky Oil will institute an Offshore Chemical Management System (OCMS), similar to that in use by Petro-Canada on Terra Nova and HMDC on Hibernia, whereby all chemicals in use offshore will be screened for environmental issues.

Completion and workover fluids which are similar in composition are pumped into wells after drilling to prepare them for production. Approximately 200 m^3 of fluids containing corrosion inhibitors, biocide and soluble salts are used per well. After completion and workover operations, wells are cleaned and the fluids are pumped into a tank. If the used fluids are highly acidic, the acid is neutralized before discharge. The fluids are also processed in an oil-water separator to reduce the level of hydrocarbons to below the guideline level of 40 mg/L specified by the OWTG.

Effluents are usually diluted 1,000-fold within 50 m of the discharge point (Sommerville et al. 1987). Sommerville et al. (1987) estimated dispersion based on numerical modelling and laboratory experiments using a 1:120 scale model to simulate plume dispersion and verified results with actual field measurements of the dispersion of rhodamine B dye. Concentration of discharged fluid in seawater beyond this distance will be 0.1 percent, the concentration of oil in water less than 40 µg/L and concentrations of aromatic hydrocarbons approximately 7 to 13 µg/L. The small amounts of these completion, packer and workover fluids would result in *negligible* effects on marine biota.

Based on experience with the exploratory wells, approximately 33 t (26.4 m^3) of excess cement will be released to the seabed per well, and will kill some benthos locally. If the cement remains in a pile, it will act as an artificial reef, be colonized by epifaunal animals and attract fish. The effects (either *negative* or *positive*) of the cement on benthos would be *negligible*.

Blowout preventer fluid is used in the blowout preventer stacks during drilling. The fluids are usually glycol-water mixes, but oil may also be used. Glycol-water mixes will be used at White Rose and will have a low toxicity. Periodic testing of the blowout preventer is required by regulations. The approximate 1 m^3 of the fluid released per test will be quickly dispersed. Periodic releases of this small amount of glycol will have a *negligible* effect on marine biota.

Well treatment fluids recovered from operations will be treated to reduce oil concentrations to levels specified by the OWTG (maximum of 40 mg/L). Time series of raw and averaged data from analysis of treated and discharged fluids will be submitted to the Chief Conservation Officer on an approved schedule.

Well treatment fluids containing diesel oil or oil with a high aromatic content will not be used unless recovered and recycled, or transferred to shore. Strongly acidic fluids will be neutralized before discharge. A chemical management plan (OCMs) will be developed with the chemical suppliers and submitted to the C-NOPB as part of the EPPs. Husky Oil used the SBM, IA-35 fluid during 1999 in order to mitigate the effects of any cushion spillage during well flow-back.

Small volumes of treated effluent will affect water quality in the immediate vicinity of the discharge; these effects will be *low magnitude* (rating = 1), *very small* in *geographic extent* (rating = 1) and *short duration* (rating = 3) (Table 4.3-2). Effects on plankton from release of other drilling fluids will likely be transitory and sublethal because small volumes will be released and toxicity levels will be low. This will result in a *negligible not significant* cumulative effect, for White Rose and the other developments combined.

Direct effects on fish from the release of other drilling fluids are unlikely. A major concern related to the release of oily water is the potential to taint fish. As described earlier, fish tainting will be monitored and all sources of hydrocarbons that could be released during field development and production will be considered. If tainted fish are found, the source(s) will be investigated and further mitigation measures will be implemented.

4.3.1.6 Deck Drainage

Deck drainage from the MODU, will be isolated from the main sources of oily waste. For example, the deck drainage system will not collect discharges from drip pans under machinery. Wastes and fluids from drip pans will be recovered and recycled, or transferred to shore for disposal in an approved manner.

A closed drain system will collect leakage and drainage of hydrocarbons from mud-handling operations. An open water drain will collect drainage from machinery spaces and working areas. Liquids will pass through an oil-water separator and the oily effluent from the separator will be collected for disposal. The treated water will be discharged over the side. Deck drainage will be processed to meet the OWTG which currently call for no more than 15 mg/L of oil in discharged water. Concentrations greater than this are considered to exceed normal operating practice and have to be reported within 24 h to the Chief Conservation Officer.

The deck drainage system on drilling rigs is separate from the system used to collect waste from machinery spaces as specified in the OWTG. Deck drainage is typically collected via pollution pans located under the rig floor. Drainage is routed to a skimmer tank and discharged via a single point. Deck drainage that is contaminated with oil is treated to the OWTG, which specify that the discharge will contain 15 mg/L or less of oil. Oil concentrations in the discharge exceeding 15 mg/L are considered to have exceeded normal operating practice and have to be reported to the Chief Conservation Officer within 24 h.

As specified in the OWTG, rigs will be equipped with drip trays, curbs and gutters and other devices to prevent spilled or leaked materials from entering the water. Waste material from drip pans and work spaces will be collected in a closed system designed for that purpose, as specified in OWTG, and will be returned to the process cycle, recycled, burned or transferred ashore by supply boat.

Effects on water quality from treated deck drainage will be *low magnitude* (1), *very small* in *geographic extent* (1), and *medium duration* (3) (Table 4.3-2). Effects will be additive with other projects but the cumulative effect will not exceed this rating. The effect on water quality will be *not significant*.

Deck drainage is unlikely to have any direct effects on fish. As discussed earlier, fish tainting will be monitored as part of an operational EEM program.

4.3.1.7 Hydrostatic Testing Fluids

Hydrostatic Tests of Flowlines

Subsea flowlines are used to transport oil, gas and water from the templates to the production facility and from the production facility to the templates. A leak in these lines could result in a spill of hydrocarbons. To guard against this occurrence, hydrostatic tests are conducted prior to First Oil on all the flowlines and connections to test their integrity.

At First Oil, not all wells will be drilled. This work will be done later in field life. But all flowlines will be laid for First Oil and all the lines will be tested. The flowlines that are not needed until later will be suspended then tested again at the time of connection to the templates to ensure the integrity of the lines and the new connections.

Composition of Test Fluid

The test fluid is comprised of seawater with additives to prevent corrosion and microbial growth in the lines (Table 4.3-8).

Table 4.3-8 Chemical Additives in Hydrostatic Testing Fluids

Name	Description	Rate
Ceca Norust 420	Oxygen Scavenger Corrosion Inhibitor Biocide	800 to 1,300 ppm
Fluoresceine	Dye	40 ppm
Glycol		To be Determined

Upon completion of the test the fluid will be purged into the sea and the unused portion will be shipped to shore for disposal. Ceca Norust 420 has an LC_{50} of 60 ppm on brown shrimp, and Glycol has a 96-hr LC_{50} of 1,000 ppm. When these fluids are released into the sea, they will be immediately diluted and thus it is expected that the solution will not be hazardous to marine life.

Volumes of Liquids

The volume of liquid that will be used during the test is calculated based on two scenarios, giving a range of volumes that can be expected. The volumes and assumptions can be found below.

Assumptions:

1. | | | |
   |---|---|---|
   | Drill Centres | 2 to 3 | |
   | Production Lines | 12" | At all drill centres |
   | Test Lines | 12" | At all drill centres |
   | Gas Lift Lines | 6" | At all drill centres |
   | Gas Injection Lines | 6" | At all drill centres |
   | Water Injection Lines | 10" | At all drill centres |

2. Drill Centres are approximately 2 to 3 km from the Production Facility.

3. Full field production scenario was used for calculations.

4. Diameters above are assumed to be internal diameters.

5. A safety factor of 1.5 is applied to a volume to account for piping at the templates, leaks, etc.

Based on two drill centres and a distance of 2 km from the drill centre to the Production Facility a minimum value of 1,400 m^3 is calculated and based on three drill centres and a distance of 3 km from the drill centre to the Production Facility an estimated maximum volume of 3,100 m^3 is obtained.

Effects on marine biota will be *negligible*. Effects on water quality will be *negligible* to *low magnitude*, *very localized*, and *short duration* (Table 4.3-2). Effects with other projects will be *additive* but the cumulative effects will not extend beyond *negligible*. Effects on fish and fish habitat of hydrostatic tests are *not significant* (Table 4.3-3).

4.3.1.8 Cooling Water

For equipment such as top-drives and draw-works, seawater is used for cooling; it is pumped through heat exchangers and discharged overboard without additives or treatment. For most other drilling rig systems, cooling is via a closed loop system. Fluids used in closed loop cooling systems are tested for compliance prior to discharge. If chlorine is used, the Chief Conservation Officer may impose restrictions on the level of residual chlorine in the water being discharged. Proposals for the use of biocides other than chlorine will be submitted to the Chief Conservation Officer as per the current OWTG (NEB, C-NOPB and C-NSOPB 1996).

Effects of the discharge of these small amounts of cooling water on fish will be *negligible* and not significant as will the cumulative effects of cooling waters from other platforms (Hibernia and Terra Nova).

4.3.1.9 Sanitary and Domestic Waste

The total number of persons on a MODU at any one time will be about 85 to 120. For a floating drilling platform accommodating about 100 people, Mobil (1985) estimated that grey water discharge would be 40 m^3/d and that black water discharge would be 19 m^3/d. The sanitary and food waste will be macerated to a particle size of 6 mm or less and included in the discharge as per OWTG. Typically the wastewater is collected via a vacuum/gravity septic system where it is treated and tested for compliance and discharged.

Organic matter will be quickly dispersed and degraded by bacteria. The effects on receiving waters and its inhabitants of this small amount of organic matter and nutrients will be *negligible* and not significant as will the cumulative effects with other projects and shipping discharges.

4.3.1.10 Garbage and Other Waste

Garbage, suitable for incineration may be incinerated, if a suitable incinerator is available on board. All non-combustible material and garbage, if not incinerated, will be transferred ashore for disposal.

Combustible materials such as oily rags, paint cans, and so forth will be placed in separate hazardous materials containers and transferred ashore. Most rigs have routine recycling programs that identify 5 to 10 percent of all garbage to be handled as recyclable materials.

No garbage will be discharged over the side and thus there will be no interaction with the marine environment. This is similar to the other projects (Hibernia and Terra Nova) and thus the cumulative effects will be non-existent or *negligible*.

Sludges from oil-water separators, spent lubricants, all plastic material, glass and metal wastes will be transferred to shore for appropriate handling, including reuse and recycling where possible.

Excess chemicals or chemicals in damaged containers will not be discharged into the sea. They will be returned to shore by supply boat. Spent or excess acid will be disposed of in a manner approved by the C-NOPB or designate.

No waste material that is hazardous to marine life will be discharged over the side and so, there will be no interaction with the environment and no effects on the marine environment. This is similar to the other projects on the Grand Banks and thus the cumulative effects will be *negligible*.

Any chemical that is used in drilling and goes downhole will be evaluated by the Operator according to C-NOPB instruction. An OCMS will be in place as part of both the Drilling and Operational EPPs.

Substances not mentioned above or in the current OWTG (NEB, C-NOPB and C-NSOPB 1996) will not be discharged without prior notification and approval of the Chief Conservation Officer.

4.3.1.11 Small Spills

Fuel, drilling muds and other chemicals will be transported by supply vessel from the onshore facilities to the drilling rig. Small amounts of these materials could be spilled, during transfer to the drilling rig.

All fuel, chemicals and wastes will be handled in a manner that minimizes or eliminates routine spillage and accidents. The EPP (Chapter 8) will provide details of safe fuel, chemical, waste handling and storage procedures. Workers will be trained in these procedures.

The EPP will also contain detailed measures for preparing for and responding to spills, including the use of cleanup equipment, training of personnel and identification of personnel to direct cleanup efforts, lines of communications and organizations that could assist cleanup operations. All cleanup measures and procedures will be specified in the EPP. More detailed information on spills is included in Chapter 5 and in the Contingency Planning in Chapter 6.

4.3.1.12 Ballast Water

On floating drill rigs and supply boats, ballast water is stored in dedicated ballast tanks. No oil is present or stored in ballast tanks and so none will be present in the discharged ballast water. If oil is suspected to be in the water, it will be tested and, if necessary, treated to ensure that oil concentrations in the discharge do not exceed 15 mg/L, as required by the current OWTG (NEB, C-NOPB and C-NSOPB 1996).

4.3.1.13 Bilge Water

Bilge water often contains oil and grease that originate in the engine room and machinery spaces. Prior to discharge, bilge water will be treated to meet the current OWTG (NEB, C-NOPB and C-NSOPB 1996), which specify that the discharge will contain 15 mg/L or less of oil. Oil concentrations in the discharge exceeding 15 mg/L are considered to have exceeded normal operating practice and will be reported to the Chief Conservation Officer within 24 h.

4.3.1.14 Produced Fluids

Produced gas and fluids will be separated on the rig. Gas, oil and condensate, if present, will be flared on the rig during well testing. The flare boom contains a special burner that atomizes the oil and/or gas and mixes it with air. This allows for relatively complete combustion and minimizes air pollution. Produced water, which has been separated from the gas, oil and condensate will be treated on site to meet the current OWTG (NEB, C-NOPB and C-NSOPB 1996). Produced water is treated in a hydrocyclone to reduce the oil content to 40 mg/L or less averaged over a 30-d period and discharged. Average oil concentrations in the discharge stream that exceed 80 mg/L over any 48-h period are considered to have exceeded normal operating practice and will be reported to the Chief Conservation Officer within 24 h.

Very little, if any, produced water will be discharged during development drilling. There may be small amounts of produced water discharged for brief periods of time during well testing.

4.3.1.15 Effects of Release of Produced Water

Produced water is formation water that is produced and released well into the operating life of a development. It is discussed in detail in the production phase assessment (Section 4.3.2.5) of effects on fish and fish habitat.

The main concern with the discharge of treated produced water is the perception that the tainting of fish could occur. Tainting imparts an oily taste to fish and makes them unpalatable and of no commercial value.

Discharged treated oily water diluted by a factor of 100 (> 60 ppb) will induce induction of the aryl hydrocarbon hydroxylase (AHH) enzyme system in fish (Davies et al. 1981). Little or no AHH activity was noted in fish exposed to produced water diluted by a factor of 500. Fish exposed to various dilutions of produced water for 20 days showed little or no histological damage while those exposed for 30 days did (Davies et al. 1981). Sublethal effects on fish could be expected in the immediate vicinity of the platform and would mainly affect resident fish.

Produced water can contain benzene, toluene, and xylene (Sommerville et al. 1987) that could cause tainting in fish. However, the low input and rapid dilution of produced water would reduce the risk of tainting in fish to an insignificant level (GESAMP 1993). If tainting did occur, it would only affect fish close to the rig within a fishing exclusion zone. In general, most of the compounds in produced water are of low acute toxicity and dispersion and degradation should limit effects to the immediate vicinity of the discharge (Sommerville et al. 1987). Somerville et al. (1987) do caution that site specific aspects must be considered and GESAMP (1993) point out that few studies have been conducted on sublethal or chronic effects on marine organisms.

Tests with Hibernia crude (water soluble fraction (WSF)) have shown that a concentration of approximately 0.5 ppm will impart a taint to cod after a 24-h exposure and that concentrations of less than 0.2 ppm will taint cod after an exposure of three days (Ernst et al. 1987). Flatfish near offshore platforms may become tainted if hydrocarbon concentrations in sediments exceed 200 ppm dry weight (S.L. Ross and LFA 1993). Although it has been shown that flatfish can bio-accumulate hydrocarbons in their livers from drill cuttings, it is unclear whether flatfish will accumulate enough hydrocarbons in muscle tissue to cause tainting (S.L. Ross and LFA 1993). Dilution by a factor of 1,000 would occur within 50 m downstream of the discharge (Sommerville et al. 1987) and oil will not reach the sea bed. It is very unlikely that a fish would be subjected to oil concentration of sufficient magnitude to cause tainting from these small intermittent discharges. Effects of treated oily waste on fish would be *negligible*. Cumulative effects will also be *negligible* and not significant.

4.3.1.16 Atmospheric Emissions

During development drilling, there will be four sources of atmospheric emissions:

1. burning of well fluids during production tests and well clean-ups (burner boom emissions);

2. engine, generator and heating exhausts from the drill rigs, supply vessels and multipurpose vessels;

3. mud, degassing and other mudroom exhausts; and

4. fugitive emissions.

Production testing and clean-up of the wells is critical to the determination of the initial reservoir conditions and to prepare the well for production. Two individual reservoir units will be tested per well. Each test will produce less than 1,000 m^3 of mixed hydrocarbon liquids. Hydrocarbons produced by the tests and some completion fluid will be burned with burner booms. The emissions from these booms will contain relatively large amounts of particulate matter containing hydrocarbons and a visible fire and smoke plume will be evident. In addition to the smoke and particulate matter, emissions will also contain unburned hydrocarbons, and oxides of nitrogen (NO_x), carbon monoxide (CO) and sulphur dioxide (SO_2).

Exhaust gases will also be emitted from generators, engines and heaters on board the drill rigs and the support vessels. Exhaust gases will contain oxides of nitrogen, carbon monoxide and sulphur dioxide and burned hydrocarbons. Fuel (normally diesel) and equipment will be carefully selected and maintained for maximum combustion efficiency. It is estimated that engine exhausts from drilling and workover will be approximately 5×10^6 m^3/d per rig (CO, NO_x, mixed hydrocarbons and particulates) (Mobil 1985).

Small amounts of gas will also be vented through flame arresters on storage tanks on the drill rig. In addition, there will be some small amounts of fugitive emissions such as hydrocarbon losses at valves and seals, and particulate matter from cement and chemical powders.

In general, the effects of atmospheric emissions will be *negligible* because emissions of potentially harmful materials will be small and they will rapidly disperse to undetectable levels.

Emissions are discussed in more detail in Section 4.3.2.13.

4.3.1.17 Effects of Ships and Boats

Each drilling rig will be supported by several vessels of 12,000+ HP and bollard pull of 150 t. These will be supply vessels commonly used to support offshore oil field development. They will transport pipe, liners, casing cement, drilling muds, chemicals, fresh water, food and all the other material necessary for drilling. One vessel will remain near each rig on standby. This type of vessel also will be used to redirect icebergs that pose a threat to the drilling rig(s).

Discharges from the vessels are discussed in previous sections. All discharges from vessels, including sanitary and domestic waste and bilge water, will be treated according to the current OWTG (NEB, C-NOPB and C-NSOPB 1996). Overall, effects of vessel discharges, including cumulative effects on fish and fish habitat, would be *negligible* and not significant. Potential effects related to noise are discussed in below.

4.3.1.18 Effects of Helicopters

Personnel and light supplies will be transported to and from the drilling rig via helicopters (Super Puma class) with flights occurring approximately four to five times per week.

Potential effects of helicopters on the marine environment are mainly related to noise, which is discussed in the following section.

4.3.1.19 Effects of Noise

The sea is a naturally noisy environment. Natural ambient noise is often related to sea state. Ambient noise tends to increase with increasing wind speed and wave height (Table 4.3-9). In many areas, shipping is a major contributor to ambient noise.

Disturbance related to underwater and air-borne noise could be caused by the drilling platforms and by mobile sources such as supply boats and helicopters. Noise does not transmit well from air to water and so effects of helicopter overflights are *negligible* on fish.

Drilling exploratory wells will necessitate the use of MODUs; semi-submersible rigs or drill ships are typically used on the Grand Banks. Generally, underwater noise levels produced by semisubmersible drill rigs are lower than those produced by drillships (Richardson et al. 1995). Noise from a semi-submersible drilling rig working in 114 m water depth in the Bering Sea did not exceed ambient noise levels beyond a range of 1 km (Greene 1986). Support boats were also present at the time these measurements were taken. In contrast, noise produced by working drill ships did not decline to ambient levels until distances beyond 10 km from the source (Richardson et al. 1995).

Table 4.3-9 Natural and Development-Related Underwater Noise Levels

Source	Broadband Noise Level (dB re 1 μPa[1])	Source Levels at Dominant Frequencies	
		Hz	Noise Level dB re 1 μPa[1]
Ambient Noise			
Wind < 1.8 km/h	-	100	60
Wind 20.4 to 29.7 km/h	-	100	97
Wind 40.8 to 50.0 km/h	-	100	102
Heavy shipping	-	50	105
Light shipping	-	50	86
Remote shipping	-	50	81
TNT explosion			
0.5 kg at 60 m	267	21	-
Seismic airguns	216-259	50-100	-
Depth sounder	180+	12,000+	-
Semisubmersible drilling rig (working)	154	7-14, 29, 70	-
Drillship (working in 20 m water depth)	174-185	to 600	-
Supply boats			
with propeller nozzles	-10	-	-
with bow thrusters operating	+11	-	-
Large Tanker	186	100+, 125	177
Supertanker	190->205	70	175
Super Puma Helicopter at 300 m above sea level			
Received level at sea surface	-	20, 50	105-110
Received level at 3 to 18 m depth	-	-	65-70

Source: Richardson et al. (1995)
[1] 3rd octave band level

Seismic exploration activity associated with White Rose or other oil developments on the Grand Banks has the potential to affect fish and habitat. Seismic vessels conduct surveys by towing arrays of airguns at the surface (6 m depth), which create noise impulses by rapid release of compressed air. Effects on fish can be either physical damage (normally limited to eggs and larvae within a few metres of the airguns) or behavioural (for example, avoidance). Extensive reviews are contained in Richardson et al. (1995) and the Class Environmental Assessment of Seismic Exploration on the Scotian Shelf (Davis et al. 1998). Reported effects on fish catches are somewhat contradictory, probably due to different study methods, species, environmental conditions, seismic sources, and so forth. Nonetheless, some reductions in catches are likely in the vicinity of seismic exploration activities due to exclusion of fishing vessels from exploration areas and possibly some avoidance behaviour on the part of the fish (Davis et al. 1998). Effects on fisheries are further discussed in the SEIS (Part Two).

Fish vary widely in their ability to hear sounds. Some fish have very good auditory capabilities. In many of these species, such as the herring, the swim bladder is connected directly to the inner ear. For herring, the upper frequency limit of hearing ranges from 4 to 13 kHz (Enger 1967). The upper limit of hearing in fish without this type of connection is only approximately 1 to 1.2 kHz (Enger 1967). The herring is also relatively sensitive to sound. At 50 to 1200 Hz, its hearing threshold is about 75 to 80 dB re 1 μPa (Enger 1967). In contrast, cod do not have a direct connection between swim bladder and inner ear, and are less sensitive to sound than are some other species of fish (Olsen 1969).

Some species of fish have no direct connection between the swim bladder and ear but have other adaptations to enhance hearing. These fish, along with those having a direct connection between swim bladder and ear, have been called "hearing specialists". Although it is difficult to compare hearing capabilities in air and water, the hearing sensitivity of hearing specialists is similar to that of other vertebrates after standardizing units (Popper and Fay 1993).

Underwater noise can scare some fish. Sudden changes in noise level can cause fish to dive or to avoid the sound by changing direction. Time of year, whether the fish have recently eaten, and the nature of the sound all may determine whether fish react to underwater noise.

Mobile Sources of Sound

Short, sharp sounds can startle herring. In one study, the fish changed direction and moved away from the source, but schooling behaviour was not affected (Blaxter et al. 1981). The fish reacted to sounds of 144 dB re 1 μPa at 80 or 92 Hz. However, when the sound was 'ramped up', sounds needed to be 5 dB higher to elicit the same response.

Schwarz and Greer (1984) studied the responses of penned herring to vessel and echosounder sounds. Recorded sounds were played back from a projector just outside a 3.3 x 3.3 m experimental pen. Received sound levels in the centre of the pen were 105 to 111 dB re 1 μPa. The three kinds of responses noted by Schwarz and Greer (1984) were:

1. *avoidance*, in which the fish formed a compact school and moved slowly away from the sound source,
2. *alarm*, in which the school packed, fled at high speed, dove repeatedly, and quickly changed directions, and
3. *startle*, in which fish flexed their bodies powerfully and then swam at high speed for 5 to 10 seconds without changing direction; school formation was not affected.

Schwartz and Greer (1984) did not observe startle responses to any playback sounds. The sounds of large vessels or accelerating small vessels mainly caused avoidance responses among the herring. The startle response was occasionally observed in response to other stimuli. Avoidance ended within 10 s of the "departure" of the vessel. When sounds were of equal received level, sounds of a larger vessel (dominated by lower frequencies) elicited a stronger reaction. The herring did not react to a 28 kHz echosounder or a 165 kHz sonar. Twenty-five percent of the fish groups habituated to the sound of the large vessel and 75 percent of the responsive fish groups habituated to the sound of the small boat. Chapman and Hawkins (1969) also noted that fish adjust rapidly to high sound levels.

The reactions of fish to ship sounds in the field have been measured with a forward looking sonar and a downward looking echosounder. Sound produced by a ship varies with aspect and is lowest directly ahead of the ship and highest within butterfly-shaped lobes to the side of the ship (Misund et al. 1996). Because of this directivity, fish that react to ship sounds do so by swimming in the same direction as the ship and will be guided ahead of it (Misund 1997). In other instances, fish will avoid the ship by swimming away from the path and will become relatively concentrated to the side of the ship (Misund 1997). Most schools of fish will not show avoidance if they are not in the path of the vessel. When the vessel passes over fish, some species, in some cases, show sudden escape responses that include lateral avoidance and/or downward compression of the school (Misund 1997). Avoidance reactions are quite variable and depend on species, life history stage, behaviour, time of day, whether the fish have fed, and sound propagation characteristics of the water (Misund 1997).

Effects of passage of a White Rose supply vessel will be transitory and no greater than that of passage of a fishing boat. Effects of supply vessels on fish behaviour will be *low magnitude* (1), *not extensive geographically* (2) and *medium duration* (Table 4.3-2). This will translate into *negligible* and thus *not significant* effects on fish and fish habitat.

Additional seismic exploration in support of White Rose is currently not expected to be required. The amount of future seismic exploration on the Grand Banks will be highly variable and difficult to predict (J. McIntyre, pers. comm.). At present, four programs are anticipated by C-NOPB for the Newfoundland offshore (2000-2001):

1. Southern Grand Banks 9,000 km (Geco Prakla Non-exclusive 2-D);
2. Northern Grand Banks 14,000 km (GSI Non-exclusive 2-D);
3. Flemish Pass 2,300 km^2 (Petro-Canada 3-D); and
4. Flemish Pass 2,200 km^2 (Chevron 3-D).

If these programs are typical of what will occur during White Rose activities then their effects will be additive with those of White Rose. Davis et al. (1998) considered the effects of seismic exploration on the Scotian Shelf on adult commercial fish and invertebrates to be *negligible* and there is no reason to change this judgement for White Rose or other potential seismic activity on the Grand Banks. However, these authors did conclude that effects on fish eggs and larvae could be minor, sublocal, short term and likely. Similar cumulative effects can be expected for the Grand Banks unless the technology and level of activity changes greatly in the future. Thus, the cumulative effects of White Rose and seismic exploration on fish can be expected to be adverse, of *low magnitude*, *limited geographic extent*, *and short duration*. These cumulative effects are considered *not significant*.

Stationary Sources of Sound

Chapman and Hawkins (1969) and Pearson et al. (1992) conducted experiments to determine effects of strong noise pulses on fish. They used airguns with source levels of 220 to 223 db re 1 µPa. They noted startle responses at received levels of 200 to 205 dB re 1 µPa, alarm responses at 177 to 199 dB, an overall threshold for the above behavioural response at about 180 dB, and an extrapolated threshold of approximately 161 dB for subtle changes in the behaviour. In both tests, fish returned to pre-exposure behaviours within 20 to 60 min after cessation of the experiment. However, the habituation does not endure, and resumption of the disturbing activity may again elicit disturbance responses from the same fish.

Noises emitted by a drilling rig are much lower in magnitude, but more continuous, than those discussed above. The fact that fish are well-known to be attracted to offshore drilling and production platforms (Stanley and Wilson 1990; Black et al. 1994) indicates that fish adapt well to noises associated with offshore oil exploration. Effects of noise from drill rigs on fish and fish behaviour in the study area will be *negligible*. Similarly, cumulative effects will be *negligible* and not significant.

4.3.2 Effects of Normal Production and Maintenance Operations

Production and maintenance activities will be continuous throughout the 12 to 14-year lifespan of the development. This section deals with effects of normal production operations and maintenance, including loading of crude oil onto tankers. Transportation of crude oil is discussed in a following section.

Potential interactions between production and maintenance activities and ecosystem elements are shown in Table 4.3-1. The environmental effects assessment for fish and fish habitat is contained in Table 4.3-10 and significance ratings are summarized in Table 4.3-11 and discussed in the following sections.

Table 4.3-10 Environmental Effects Assessment on Fish and Fish Habitat During Production (A) and Decommissioning (B) Phases

Valued Environmental Component: Fish and Fish Habitat Phases: Production and Decommissioning								
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
Production and Decommissioning Phase			**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/Socio-Cultural and Economic Context**
A: PRODUCTION PHASE								
Presence of Structures								
No Fishing Zone	Safe Refuge (P)		1	3	6	5	R	1
Artificial Reef Effect	Food and Shelter (P)		1	2	6	5	R	1
Subsea Structures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Surface Structures	Shelter (P)		0	1	6	5	R	1
Lights and Flares	Attraction (A)		0	1	6	5	R	1
Underwater Maintenance	Food Supply (A)	Material/ Method Selection	0	1	1	5	R	1
Injection Water	Contamination (A)	Safety Plan	0	1	1	5	R	1
Produced Water	Contamination (A)	Treatment	1	2	6	5	R	1
Storage Displacement Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cooling Water	Growth (P); Shock (A)		0	1	6	5	R	1
Deck Drainage	Contamination (A)	Treatment	0	1	6	5	R	1
Sanitary and Domestic Waste Water	Nutrients (P); Contamination (A)	Primary Treatment	0	1	6	5	R	1
Atmospheric Emissions	Water Quality (A)	Equipment Design	0	2	6	5	R	1
Ships and Boats	Disturbance (A)		0	1	4	5	R	1
Helicopters	Disturbance (A)		0	1	4	5	R	1
Noise								
FPSO	Disturbance (A)		0	2	6	5	R	1
Support Vessels	Disturbance (A)		0	2	6	5	R	1
Helicopters	Disturbance (A)		0	1	4	5	R	1
Shore Facilities [a]	N/A	N/A						
Offshore Oil Spills [b]								
B: DECOMMISSIONING PHASE								
Offshore Decommissioning	Loss of Refuge and Reef (A);		1	1	6	5	R	2
	Stop Disturbance (P);		1	1	6	5	R	2
	Stop Contamination (P)		1	1	6	5	R	2
Abandonment	No Effect	Removal of subsea material	N/A	N/A	N/A	N/A	R	2

Valued Environmental Component: Fish and Fish Habitat Phases: Production and Decommissioning								
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
Production and Decommissioning Phase			**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/Socio-Cultural and Economic Context**

KEY

Magnitude:
0 = Negligible, essentially no effect.
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility:
R = Reversible
I = Irreversible
(Population Level)

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

N/A = Not Applicable

[a] Not applicable. There will not be any new onshore facilities. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

Table 4.3-11 Significance of Residual Environmental Effects on Fish and Fish Habitat – Production and Decommissioning Phase

Valued Environmental Component: Fish and Fish Habitat				
Project Activity	**Significance Rating**	**Level of Confidence**	**Likelihood**	
	Significance of Predicted Residual Environmental Effects		**Probability of Occurrence**	**Scientific Certainty**
PHASE: PRODUCTION				
Presence of Structures				
No Fishing Zone	P/NS	3	3	3
Artificial Reef Effect	P	3	3	3
Subsea Structures	P	3	3	3
Surface Structures	P	3	3	3
Lights and Flares	NS	3	3	3
Underwater Maintenance	NS	3	2	2
Injection Water	NS	3	2	2
Produced Water	NS	2	2	2
Storage Displacement Water	N/A	N/A	N/A	N/A
Cooling Water	NS	3	3	3
Deck Drainage	NS	2	3	2
Sanitary and Domestic Wastes	NS	3	3	3
Garbage				
Atmospheric Emissions	NS	3	3	3
Ships and Boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
FPSO	NS	3	3	3
Support Vessels	NS	3	3	2
Helicopters	NS	3	1	3
Shore Facilities [a]				
Accidents	NS	2	1	3
Offshore Oil Spills [b]	[a]	[a]	[a]	[a]
PHASE: DECOMMISSIONING				
Offshore Decommissioning	P	3	3	3
Abandonment	P	3	3	3

Key:

Residual environmental Effect Rating:
S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) *and* geographic extent >100 km^2 (4 or greater rating).

Level of Confidence based on professional judgement
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgement
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[a.] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

The FPSO will be a steel hulled ice-strengthened, ship-shaped vessel with an integral crude oil storage. The FPSO will contain facilities, machinery and equipment for:

- receiving and processing crude oil;
- transferring processed crude to tankers;
- injecting water;
- treating produced water;
- compressing gas for injection;
- power generation;
- safety and control systems;
- communications;
- accommodation;
- laboratory;
- workshops;
- laydown facility;
- fuel storage; and
- helicopter pad.

One or more double-sided-hulled, ice-reinforced shuttle tankers up to 135,000 t deadweight will be used to transport the crude oil from the FPSO to a transshipment facility or direct to market.

The FPSO will be supported by two supply and standby vessels. On average, there will be four to five to helicopter round trips to the FPSO per week.

4.3.2.1 Presence of Structures

The FPSO and supply vessels will be on site during the 12 to 14-year life of the project. There also will be a drill rig in the vicinity for three to four years after First Oil and intermittently for short periods of time after that. During this time, subsea structures will be present on the sea floor.

Effects on Fish

Effects of subsea structures and the artificial reef effect have already been discussed in Section 4.3.1.1.

Effects of the safety zone are also discussed in Section 4.3.1.1.

Biofouling

Biofouling has been previously discussed in Section 4.3.1.1.

Effects on Benthic Animals

The effects of trawling on the benthos were discussed in Section 4.3.1.1. It was concluded that trawling may have *adverse* effects on sediments. Thus, the presence of a no fishing safety zone around the White Rose Development could have *positive* effects by allowing recovery of the benthos in the zone.

The effects of structures on benthos will depend on the state of the fisheries over the development period. If the present low levels of bottom trawling are maintained, then the no fishing zone would produce *negligible* effects on benthos. On the other hand, if the fisheries recover, then the relative effects of the no fishing zone on the benthos are likely to be *positive, low magnitude* (1), *long duration* (5) and *not geographically extensive* (3) (Table 4.3-10). The cumulative effects considering Hibernia and Terra Nova would be similar and additive. The effect on fish and fish habitat will be *not significant*.

4.3.2.2 Lights and Flares

The FPSO, supply and standby vessels, and tankers will carry navigation and warning lights. Working areas will be illuminated with floodlights. The helicopter pad will be floodlit and have navigational and landing lights. Flaring is another potential source of light, however flaring from the FPSO during production is expected to occur rarely, during non-routine conditions such as operational upsets. Effects during production would be negligible, as discussed in Section 4.3.1.2. Similarly, cumulative effects would be negligible.

4.3.2.3 Maintenance of Subsea Structures

Subsea structures will require periodic inspection, cleaning to remove fouling organisms, repairs, and maintenance of corrosion-protection devices and coatings. Effects of removal of fouling organisms have been discussed in Section 4.3.1.1. Maintenance activities will disturb a small area of the bottom and cause *negligible* effects on benthic communities. Some resident fish may be disturbed, but effects will be *negligible*. Similarly, cumulative effects from Hibernia and Terra Nova would be *negligible* and not significant. There will be no interaction with pelagic fish.

Potential effects on fish could be caused by the associated noise. Effects of underwater noise were discussed in Section 4.3.1.19.

Subsea control valves associated with the Xmas trees and manifolds periodically release control fluid when operated. Husky Oil is considering use of a non-toxic control fluid as planned for the Terra Nova Development. Effects, including cumulative effects, of periodic releases of non-toxic control valve fluid will be *negligible* because amounts will be relatively small and the material will be non-toxic to marine life.

4.3.2.4 Injection Water

Water will be injected into the reservoir to enhance oil recovery by maintaining reservoir pressure. Water will be processed and pressurized for injection on the FPSO. The FPSO will be designed to inject up to 40,000 m^3/d of water into the reservoir or 2,000 to 6,000 m^3/d with a peak of 9,000 m^3/d per well. Water will be injected at an approximate pressure of 20.7 MPa.

The injection water will be filtered, chlorinated, and treated with oxygen scavengers and corrosion inhibitors, as shown in Table 4.3-12. Additives used in the treatment of the injection water will be used in minimum amounts by using accurate metering equipment.

Table 4.3-12 Injection Water Additives

Purpose	Additive	Concentration (ppm)
Biocide	Chlorine or alternative	1-2 (Cl_2)
Oxygen scavenger	Sodium or ammonium bisulphite	5-10
Scale inhibitor	Surfactants Inhibitor: organophosphate phosphino polyacrylate; polyacrylate organic phosphate esters	5-50 5-20 10-20
Corrosion inhibitors	Amines and imidazolines; aliphatic diamines; quaternary nitrogen compounds; poly-oxyalkylated amines; nitrogen heterocyclics (alkylated polymerized pyridine)	5-25

Extracting this amount of seawater will have a *negligible* effect. Some zooplankters and fish larvae will be entrained, but effects on populations from entrainment will be *negligible*. Similarly, cumulative effects of Hibernia and Terra Nova would be additive but *negligible* and not significant.

Some of the injected water may eventually be discharged as a component of produced water.

4.3.2.5 Produced Water

Subsea facilities at White Rose will consist of up to 18 to 25 subsea wells comprising up to 10 to 14 producers, six to eight water injectors and two to four gas injectors. Sea water injection will be required to provide voidage replacement and maintain reservoir pressure. A portion of the injection water may ultimately become part of produced water. Water treatment facilities on the FPSO will treat produced water to a quality that complies with the current OWTG (NEB, C-NOBP and C-NSOPB 1996).

Produced water that is treated on site will be passed through a hydrocyclone to reduce the oil content to 40 mg/L or less (averaged over a 30-d period) and discharged. Average oil concentrations in the discharge stream that exceed 80 mg/L over any 48-h period are considered to have exceeded normal operating practice and will be reported to the Chief Conservation Officer within 24 h.

The oily water produced in the process first and second stage separators is directed to hydrocyclones where the oil is separated to a stage where the remaining oil content of the water is in compliance with the current OWTG (NEB, C-NOBP and C-NSOPB 1996). If the discharge from the hydrocyclones is above specified maxima, then the contaminated water is automatically directed to the facility slop tanks and/or a cargo storage tank. This allows production to continue and provides time for the problem to be corrected by the operators. The diverted water is then allowed to settle out in the slop tank prior to discharge overboard via the slop tank arrangement.

Once the produced water is cleaned to specifications, it is piped from the hydrocyclone discharge on the FPSO, down to the main deck and then the pipe penetrates one of the side water ballast tanks and terminates at approximately 3 to 5 m below the waterline. At this, level the pipe penetrates the hull and produced water is discharged overboard. The peak field produced water is estimated at a maximum of 30,000 m^3/d.

The feasibility of using produced water to meet water injection requirements will be investigated during the detailed design process as well as the feasibility of re-injecting all produced water rather than discharging overboard.

Composition of Produced Water

Produced water can contain hydrocarbons, dissolved mineral salts, sulphur, barium, and iron (Rose and Ward 1981). Small amounts of manganese, arsenic, cadmium, chromium, silver, copper, mercury, nickel, lead, and zinc can also be found in produced water (Thomas et al. 1984). The common naturally occurring radioactive material (termed NORM) in produced water is strontium (Thomas et al. 1984; Mobil 1985).

The pH of produced water ranges from neutral to acidic with typical values of about 6.6 (Thomas et al. 1984). At Hibernia, the pH of the formation water was 5.6 (Mobil 1985). The normal pH of seawater is approximately 7.5 to 8.5.

The concentrations of toxic chemicals, that originate in the formation, in most produced waters are less than the 96-h LC_{50} levels for most species and are not of ecotoxicological concern, so there should be no acute toxicity beyond a few tens of meters of the discharge (Sommerville et al. 1987; GESAMP 1993).

Hydrocarbons will be removed in the oil-water separation system such that total concentration of hydrocarbons (formation oil plus any additives) in the produced water meets the OWTG (40 mg/L or less averaged over a 30-day period). About one third of the oil in produced water will be aromatic hydrocarbons.

Because the reservoir temperature is 110ºC, the produced water (approximately 60EC) will be warmer and less dense than the receiving water (0.7 to 7.5°C). To enhance dispersion of the produced water, it will be discharged below the sea surface. When discharged, the water will tend to rise, but in so doing, it will be mixed with the receiving water so that the temperature quickly approaches that of the receiving water.

Zone of Influence

A frequently used approach to determining a zone of influence of a particular activity or emission is to use predictive models to estimate the area (geographic extent) affected by the activity or release. This approach has been used for many offshore locations including the existing Hibernia and in-progress Terra Nova projects on the Grand Banks. Husky Oil has employed such an approach to model the behaviour of the discharged produced water and to estimate the ZOI for produced water discharge for the White Rose project (Hodgins and Hodgins 2000).

It was assumed that the treated produced water (at 60EC, 25 ppt salinity and containing 40 mg/L oil) will be discharged vertically downward from the FPSO through a 14” (0.356 m) diameter pipe at a depth of 5 m. For a flow rate of 0.35 m^3/s, the initial dilution and depth of trapping at neutral buoyancy were calculated using the U.S. Environmental Protection Agency buoyant plume model UM. Results show that the plume will jet downward about 6 m below the end of the discharge pipe and rise back on itself, and will then likely rise along the FPSO hull to the surface before being carried away by the currents. An initial bulk dilution (total volumetric dilution of the plume) of about 35:1 is expected; this value is not sensitive to the seasonal oceanographic conditions or current speed.

Vertical mixing is expected to be a reasonably strong process at White Rose since there is constant wave activity. Simulation of the further dilution by horizontal and vertical mixing showed that total dilution ranges from about 40:1 at the FPSO location, and in the slack water effluent pools near the FPSO, to over 1,000:1 within distances of the order of 10 to 15 km. The produced water will float in a thin layer at the surface in a relatively narrow plume that maintains its identity for many kilometres from the FPSO, although the shape and position are highly variable.

The ZOI for White Rose has been defined as that area where C > 0.1 mg/L at least one percent of the time and inside this zone, oil will be present at equal or higher concentrations for more than one percent of the time. The threshold was set at 0.1 mg/L based on 96-h LC_{50} toxicity tests on larvae of selected commercial fish and invertebrate species that may be sensitive to soluble aromatic hydrocarbons as low as 0.1 to 0.14 mg/L (Moore and Dwyer 1974; Hurlbut et al. 1991; Booman and Foyn 1996). This definition is conservative because the threshold is at the low end of the range for effects on fish (including sublethal effects) and because organisms in the water column will be exposed for much shorter periods than 96 h, the exposure time for the tests.

The White Rose ZOI model for produced water, using a 30,000 m^3/d discharge of 40 mg/L oil content at a 5 m depth, indicates an irregular ZOI ranging from a low of 1.8 km for produced water (a maximum estimate along the axis) in winter (Figure 4.3-3) to an extreme of 3.6 km in the fall (Figure 4.3-3) with the axis always trending southeast to southwest.

The seasonal variations in residual currents at White Rose alter the shape of the frequency distributions. During fall and winter months, storms produce strong flows in all directions which gives rise to a more circular pattern, centred on the FPSO, than in the other two seasons. By contrast, during May the residual currents are persistently flowing to the south-southeast and the resulting frequency distribution is highly skewed to that direction. The summer pattern is intermediate between these two seasonal extremes (Figure 4.3-4).

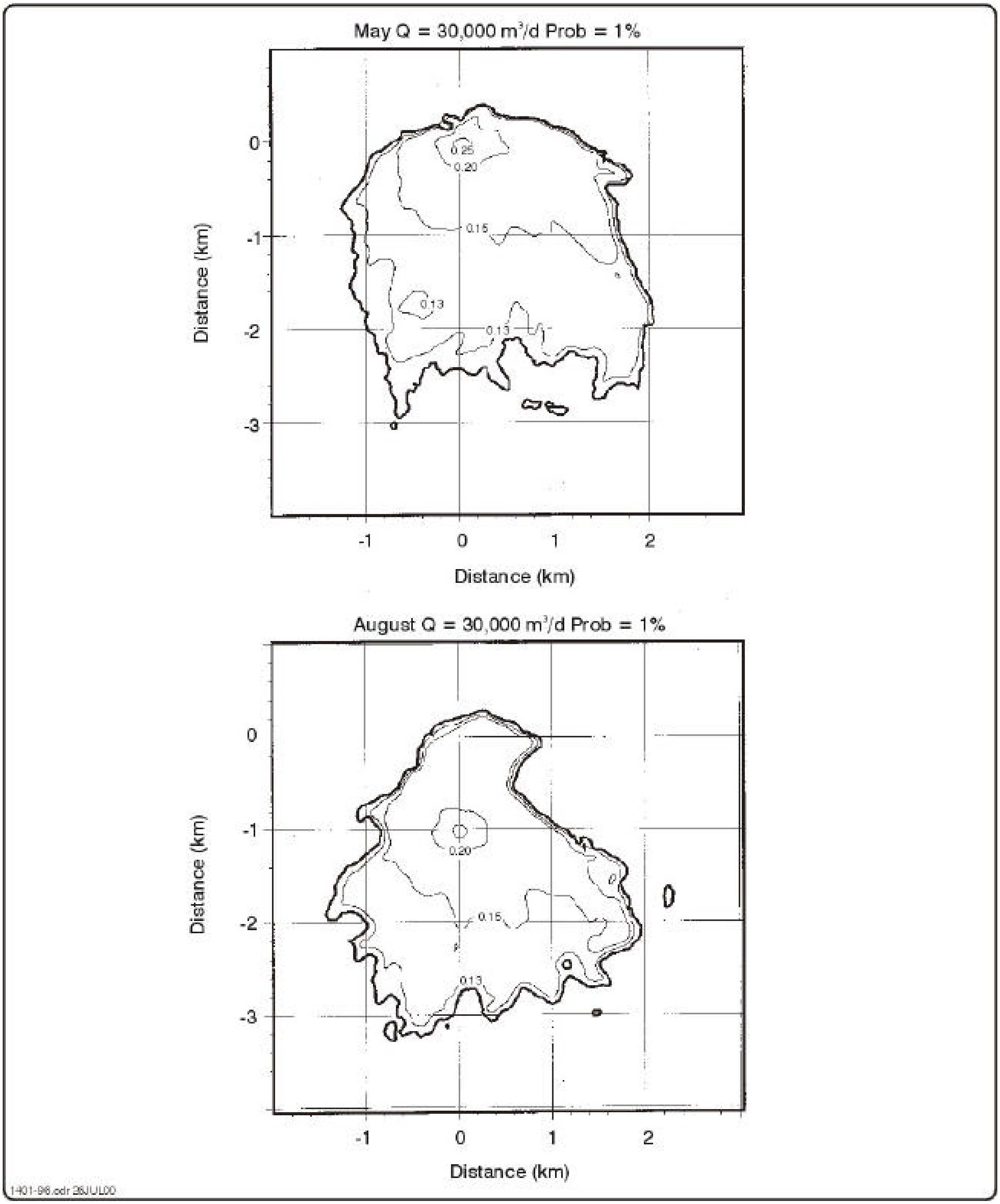
The approach used to model the ZOI results in conservative estimates because 30,000 m^3/d is the maximum expected; 40 mg/L of oil content is the maximum allowable discharge concentration, and discharge will occur at a deeper depth (to 14 m when the FPSO is fully loaded), where vertical mixing will play a larger role. In addition, the criteria of less than 0.1 mg/L for at least 1 percent of the time is also conservative and natural mixing processes are expected to reduce concentrations from 40 mg/L to less than 0.1 mg/L within 30 h, which is well below the 96-h criterion.

Predicted concentrations greater than 0.2 mg/L for at least 1 percent of the time are confined to within a few hundred metres of the FPSO (Figures 4.3-3 and 4.3-4).

The White Rose modelling study results are somewhat different than those obtained for Hibernia because of differences in the method of discharge. Modelling done for produced water at Hibernia is discharged horizontally below the thermocline. Predicted dilutions range from 170 near the discharge, a factor of 1,000 at a distance of 500 m and a factor of 1×10^4, 5 km downstream (Mobil 1985). Given this rate of dilution, the concentration of produced water in seawater would be less than 0.1 percent at distances greater than 50 m downstream of the discharge. Assuming that the discharge is treated to current OWTG, which call for concentrations of oil in discharge to be less than 40 mg/L (30-day average), concentration of oil in water would be less than 40 µg/L (40 mg/L diluted by a factor of 1,000), and concentrations of aromatic hydrocarbons would be less than 13 µg/L at distances of 50 m from the source. This dilution factor assumes the produced water will be less dense than seawater and not neutrally buoyant.

Figure 4.3–3 Produced Water Zone of Influence in Spring and Summer

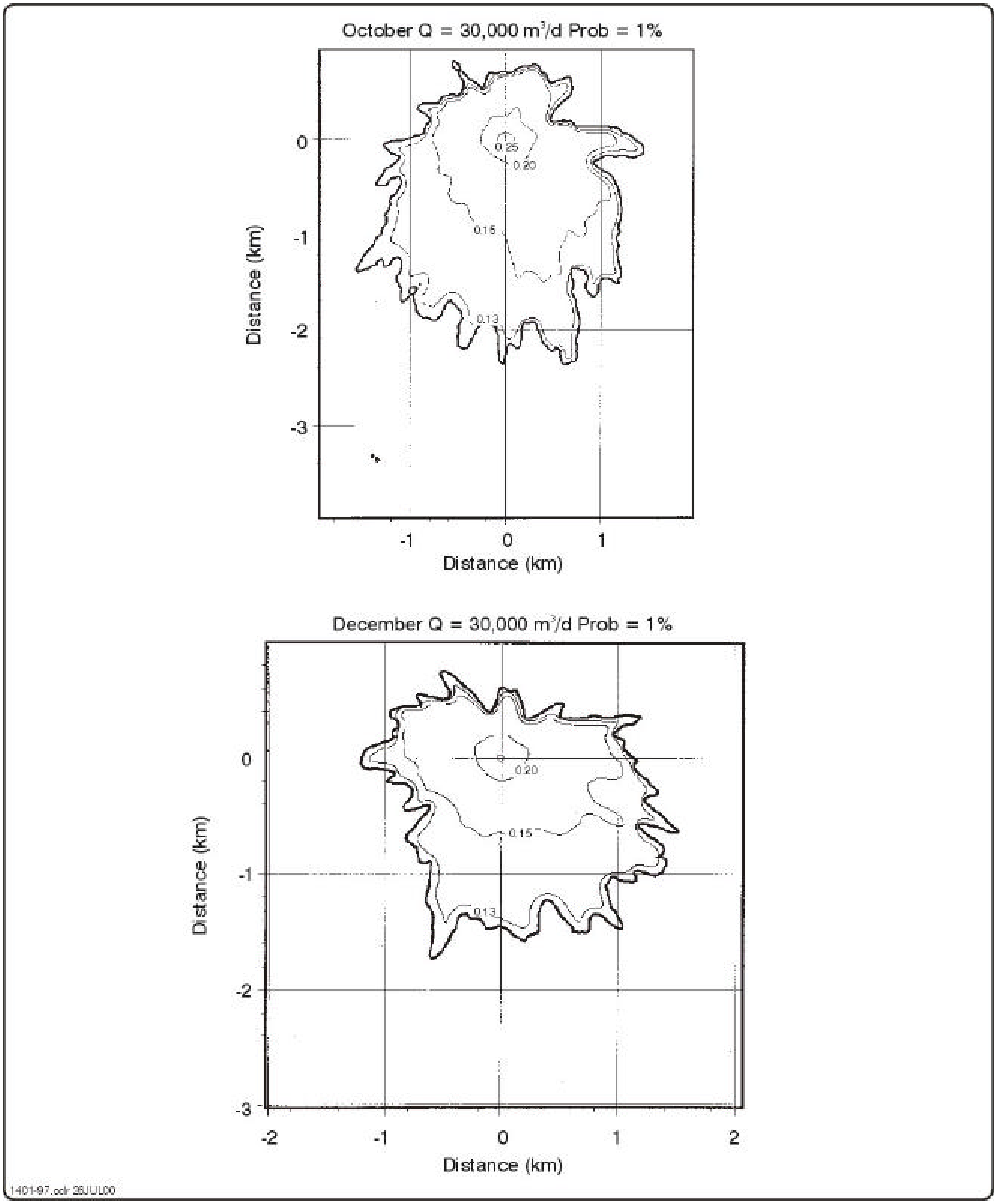
The bold contour line encloses the zone of influence where oil concentrations exceed 0.1 mg/L at least one percent of thetime. The thin contour lines show the 30-d average oil concentration (0.13, 0.15, 0.20, 0.25 mg/L) within this zone of influence.



(Source: Hodgins and Hodgins 2000)

Figure 4.3–4 Produced Water Zone of Influence in Fall and Winter

The bold contour line encloses the zone of influence where oil concentrations exceed 0.1 mg/L at least one percent of thetime. The thin contour lines show the 30-d average oil concentration (0.13, 0.15, 0.20, 0.25 mg/L) within this zone of influence.



(Source: Hodgins and Hodgins 2000)

Based on modelling studies (Hodgins and Hodgins 1998), produced water discharges at Terra Nova are similar to White Rose and are expected to have the following characteristics:

1. the water, at a temperature of approximately 60°C, will be discharged vertically downward at a depth between 12 and 18 m, depending upon the load level in the FPSO;

2. it will rise to meet the hull of the FPSO, flow upward along the hull to the surface and will then be dispersed in a thin surface layer by ocean currents; and

3. minimum dilutions, in the order of 25:1 were predicted to occur within a few hundred metres of the FPSO.

Modelling in the Gulf of Mexico predicted dilution by a factor of about 1,000 at distances of 80 to 100 m from the source (Smith et al. 1994). A dispersion model for the North Sea that assumed a discharge of 10,000 m^3 of produced water, slightly less dense than seawater, predicted dilution by a factor of 1,000 within 50 m downstream of the discharge and dilution by a factor of 3,000 within 250 m of the source (Sommerville et al. 1987).

Effects of Produced Water

The most toxic components of the produced water are the volatile hydrocarbon aromatics: benzene, toluene, ethylbenzene, xylene and PAHs. All but the PAHs, evaporate quickly and pose only a very localized threat to marine organisms (Black et al. 1994). The PAHs are more persistent and are probably responsible for biological effects near produced water outfalls (Black et al. 1994).

Produced water is generally considered to be nonhazardous with 96-h LC_{50} values of 1,000 to greater than 10,000 ppm (GESAMP 1993). Acute toxicity is unlikely at dilutions of 100-fold (Sommerville et al. 1987) or 25-fold (Hodgins and Hodgins 1998), which will occur near the discharge point.

Fouling organisms within 10 to 20 m of the outfall will likely be exposed to the chronic effects of produced waters and may accumulate oil and sustain some reduction in biomass and productivity (Gallaway et al. 1981; Sommerville et al. 1987).

In the North Sea, mussel monitoring studies showed that mussels on the platforms had hydrocarbon concentrations 60 to 100 times that of controls (Sommerville et al. 1987). At a site 6 km from the source, hydrocarbon levels in mussels were 6 to 10 times that of controls and at distances of 10 km, levels were close to those of unexposed mussels. The maximum zone of influence may have been 6 to 10 km downstream of the source. However, some of the oil accumulated in mussels may have originated from diesel oil-based drilling muds (Sommerville et al. 1987).

As previously stated, injection water additive use will be minimized, therefore, it is expected that any additives used will be diluted while in the wells and formation. The concentrations of these chemicals in most produced waters are less than the 96-h LC_{50} levels for most species and are not of ecotoxicological concern (Sommerville et al. 1987; GESAMP 1993).

Sublethal Effects

Produced water discharged in shallow water of 1.5 to 12 m depth in Louisiana caused a depression in benthic communities (Rabalais et al. 1992). Numbers of animals and numbers of species were lower out to distances of 800 m from the source. In addition, there was mortality and weight loss in oysters deployed in cages out to 400 m from discharges (Rabalais et al. 1992). Off California, there were effects on infauna 50 to 100 m from a produced water discharge on the bottom at 12 m (Osenberg et al. 1992). Condition of caged mussels (growth, somatic and gonadal mass) was depressed out to distances of 100 to 1,000 m from the outfall. Invertebrates exposed to produced water show sublethal effects and, when continuously exposed, die.

Larvae of benthic animals are generally considered to be more sensitive to oil pollution than are older life stages of invertebrates (Raimondi and Schmitt 1992). Experiments with abalone larvae off California near a produced water outlet of 2.3 $x10^6$ L/d showed substantial reduction in survivorship up to 100 m from the outfall for an early larval stage, but virtually no lethal effects on a later larval stage at distances as close as 5 m from the outfall (Raimondi and Schmitt 1992). However, there was significant failure of all larval stages to complete metamorphosis, and die, to distances of up to 100 m from the outfall. To simulate exposure of drifting larvae, larvae were exposed to the outfall for 5.5 h at a distance of 5 m. This exposure reduced the numbers of viable larvae by approximately 15 percent. After the 5.5 h exposure, there was a reduction in swimming ability of larvae to at least 100 m from the outfall.

Exposure of sea urchin embryos to produced water (Krause et al. 1992) showed that:

- the zygote was more resistant to effects than gametes;
- concentrations of produced water of 0.0001 percent significantly inhibited fertilization;
- concentrations of 1 percent produced water did not cause mortality of larvae but significantly delayed development; and
- development was delayed in a dose dependent manner; the longer the exposure, the greater the delay.

Produced water from a crude oil terminal (total organic content of 40 mg/L) at dilutions of 9 to 15 percent reduced filtering rate and increased respiration rate in a clam in a dose dependent manner (concentration x exposure; Din and Abu 1992). The exposure reduced the scope for growth in the clam by 50 to 75 percent.

The studies mentioned above were conducted in shallow water or in relation to shallow water situations, where produced water can have significant effects because of low dilution rates and because animals can be exposed for long periods of time. It may not be possible to translate these results to the deep water situation at White Rose. As stated previously, dispersion models of produced water plumes produced for the North Sea predicted dilution to 0.1 percent produced water within 50 m downstream of the discharge and dilution to 0.03 percent within 250 m of the source (Sommerville et al. 1987). Assuming treatment to current OWTG, concentration of oil in water would be less than 40 mg/L at the source and less than 40 µg/L at distances >50 m from the source. Dilution will occur rapidly and so planktonic animals will be exposed to continuously diminishing concentrations of produced water.

Untreated produced water is generally considered to be non-hazardous with 96-h LC_{50} values of 0.1 to >1 percent (GESAMP 1993). Because the offshore discharge limitation on produced-water toxicity has only recently been imposed in the Gulf OCS region, relatively few toxicity data are available. Recent work in the Gulf of Mexico found acute 96-h LC_{50} values in the 2.3 to 15.96 percent range and seven-day chronic LC_{50} values of 2.05 to 10.05 percent for treated produced water (Moffit et al. 1992). In the Gulf of Mexico, EPA produced water discharge limits are based on a seven-day test for the No Observable Effect Concentration (NOEC) on 1) survival, 2) growth and 3) fecundity. To be in compliance, the concentration of produced water at the edge of a modelled 100 m mixing zone around the discharge must be below the lowest of the three NOEC values. Mean NOEC values for the above study was from 1.38 to 1.92 percent, with growth and fecundity being more sensitive than survival. Another study evaluated acute toxicity levels of produced waters from the Norwegian sector of the North Sea (Brendehaug et al. 1992). This study found 24-h EC_{50}s to be in the 4 to 20 percent range (EC refers to Effect Concentration, the concentration at which a particular sublethal effect is noted). Given these values, produced water would be classified as essentially non toxic.

Biological Effects of Heated Water

The produced water will be discharged below the sea surface at temperatures of approximately 60°C above ambient or less. The zone of influence of elevated temperatures will be 50 m or less around the production site.

Some zooplankton and fish larvae may experience thermal shock in the immediate vicinity of the outfall. Because the area affected by elevated temperatures is so small, the numbers of affected animals are expected to be *negligible* in terms of local populations.

The produced water plume from the White Rose oilfield will be warm and of similar salinity as the receiving waters. It will rise to the surface and thus, have little potential for interacting with benthic animals.

Sessile epibenthic animals and plants may be excluded from colonizing some parts of the structure because of high temperatures and some fouling organisms may be killed by exposure to high temperatures. This mitigates the effects of biofouling on the project, as discussed in Section 4.3.1.1.

Water Quality

Produced water could affect water quality slightly downstream of the release point. Effects would be *low magnitude* (1), *localized in geographic extent* (2), and *continuous* and *long duration* (5) (Table 4.3-10).

Plankton

The threshold level above which some toxic effects on water-column organisms could be expected may be about 10 μg/L of aromatic hydrocarbons (Black et al. 1994). Assuming that aromatic hydrocarbons comprise 33 percent of the oil in produced water, concentrations of 3 μg/L of aromatic hydrocarbons could be expected within 500 m of the discharge point. Cod and herring larvae and phytoplankton appear to be unaffected by produced water (Sommerville et al. 1987). Copepods and larvae of benthic animals may be sensitive to concentrations of aromatic hydrocarbons on the order of 5 to 15 μg/L (Davies et al. 1981). Plankton in the plume of produced water would be exposed to aromatic hydrocarbon concentrations of 5 to 15 μg/L for a very short period of time because dilution would occur rapidly. After treatment, effects of produced water on the plankton would be *low magnitude* (1), *long duration* (5) and *limited in geographic extent* (2) (Table 4.3-10). Cumulative effects would have a similar rating. Any effects will be *not significant* (Table 4.3-11).

Benthos

Fouling organisms on structures within 10 to 20 m of the outfall will likely accumulate oil and sustain some reduction in biomass and productivity (Gallaway et al. 1981; Sommerville et al. 1987).

Because the plume will rise, it will not interact with benthos; therefore, effects from White Rose (and cumulatively from other projects) on the benthos will be *negligible*.

Fish

Produced water diluted by a factor of 100 (> 60 μg/L) will induce the AHH enzyme system in fish (Davies et al. 1981). Little or no AHH activity was noted in fish exposed to produced water diluted by a factor of 500. Fish exposed to various dilutions of produced water for 20 days showed little or no histological damage while those exposed for 30 days did (Davies et al. 1981). Sublethal effects on fish could be expected in the immediate vicinity of the platform and would mainly affect resident fish.

Tests with Hibernia crude WSF have shown that a concentration of approximately 0.5 ppm will impart taint a cod after a 24-h exposure and that concentrations of less than 0.2 ppm will taint cod after an exposure of three days (Ernst et al. 1987). Flatfish near offshore platforms may become tainted if hydrocarbon concentrations in sediments exceed 200 ppm dry weight (S.L. Ross and LFA 1993). Although it has been shown that flatfish can bioaccumulate hydrocarbons in their livers from drill cuttings, it is unclear whether flatfish will accumulate enough hydrocarbons in muscle tissue to cause tainting (S.L. Ross and LFA 1993). Dilution by a factor of 1,000 would occur within 50 m downstream of the discharge (Sommerville et al. 1987) and oil will not reach the sea bottom.

Produced water can contain benzene, toluene, and xylene (Sommerville et al. 1987) that could cause tainting in fish. However, the rapid dilution of produced water would reduce the risk of tainting in fish to an insignificant level (GESAMP 1993). Resident fish attracted to the area by the reef effect would be most at risk from tainting; however, because of the safety zone these fish would not be harvested. In general, most of the compounds in produced water are of low acute toxicity and dispersion and degradation should limit effects to the immediate vicinity of the discharge (Sommerville et al. 1987). Sommerville et al. (1987) do caution that site-specific aspects must be considered and the GESAMP (1993) study points out that few studies have been conducted on sublethal or chronic effects on marine organisms.

Direct effects and cumulative effects on fish and fish habitat are predicted to be *negligible* and not significant which will be verified by a monitoring program for taint. Cumulative effects are expected to be additive and *negligible* and will be monitored as described in Chapter 7.

Mitigation and Monitoring

The FPSO will be capable of treating at least 30 x 10^3 m^3/d of produced water. The water treatment system will reduce oil content of discharged produced water to levels specified in the current OWTG (NEB, C-NOPB and C-NSOPB 1996), which currently specify:

- a 30-day average concentration of 40 mg/L or less;
- that oil concentrations greater than 80 mg/L during any 48-h period of production are considered to be in exceedance of normal operating practice and are to be reported to the Chief Conservation Officer within 48 h;
- that measurement of oil concentrations be taken every 12 h;
- a daily calculation of a rolling 30-day average; and
- the measurement methods to be used.

Husky Oil will consider reducing the diameter of the exit pipe and the discharge depth, during facility design, in order to enhance exit velocity and improve dilution. Most of the oily water discharge will be produced water. A monitoring program will determine oil concentrations at various distances from the discharge and will look at pre-injection and produced water compositions. The extensive literature base on models coupled with the final field layout will be used to design the monitoring program.

A program to monitor potential tainting in fish is discussed in Chapter 7.

4.3.2.6 Other Operational Discharges

In addition to produced water, there will be other materials and liquids associated with the White Rose Development. Some of these will be released into the environment. An OCMS will be in place to screen all chemicals used offshore. Other discharges are discussed in the following sections.

4.3.2.7 Storage Displacement Water

The FPSO will have crude storage capacity on board. It will also have segregated ballast tanks to prevent contamination of ballast water with oil, so there will be no possibility of oil-contaminated ballast water or storage displacement water being discharged over the side.

Ballast water from tankers could contain larvae of epifaunal animals, which would colonize the structures. However, fouling will occur from other shipping sources without this additional source of larvae.

The potential effects (and cumulative effects) of discharge of ballast water on fish and fish habitat will be negligible.

4.3.2.8 Cooling Water

The cooling water system for the topsides and turret will be designed for sea water with an anticipated design supply and return of 3,600 m^3/h.

Cooling water will be chlorinated with sodium hypochlorite to achieve a level of 0.5 ppm of residual chlorine. Alternate methods to minimize chlorination are under consideration. This water may be discharged at temperatures of approximately 30°C above ambient. Some zooplankton and fish entrained in the intakes would be killed by the heated effluent. Potential effects (including cumulative) will be *negligible* because the volume of entrained water and the area of thermal effects will both be small (Mobil 1985).

4.3.2.9 Deck Drainage

Drainage from the decks of drill rigs and the FPSO will be isolated from the main sources of oily waste, and on the FPSO, the water will be passed through an oil-water separator. The oily effluent from the separator will be collected for disposal, and the treated water discharged over the side. Deck drainage will be processed to meet the current OWTG (NEB, C-NOPB and C-NSOPB 1996) of 15 mg/L. Oil concentrations of greater than 15 mg/L are considered to have exceeded normal operating practice and are to be reported within 24 h to the Chief Conservation Officer.

Small volumes of treated deck drainage containing small amounts of oil will cause *low magnitude* (0-1), *very localized* (1), *long duration* (5) effects on water quality (Table 4.4-10). The potential effects of deck drainage on plankton are likely to be transitory and sublethal and will affect only a small volume of water; effects (including cumulative) will be *negligible*. Fish tainting will be monitored. Any effects on fish and fish habitat will be *not significant* (Table 4.3-11).

4.3.2.10 Sanitary and Domestic Waste

The topside facility on the FPSO will accommodate approximately 80 people. In addition, there will be personnel crewing the drill rig(s), supply and standby boats.

Grey water from showers, sinks and washers will be routed to the treatment plant and then into the sea. Sewage and other domestic effluents will be treated to meet the current OWTG (NEB, C-NOPB and C-NSOPB 1996). Treatment will be as required for operations in offshore deep waters. Domestic wastes will be macerated to a particle size of 6 mm or smaller before discharge. Sanitary wastes will be treated and the effluent discharged overboard. For an FPSO, Mobil (1985) estimated 19 m^3/d of sewage and 34 m^3/d of domestic waste. Actual numbers at White Rose will be proportional to the number of people on board and are expected to be on the order of 19 m^3/d black water and 40 m^3/d of grey water.

Organic matter will be quickly dispersed and degraded by bacteria. Effects of this small amount of organic matter and nutrients to receiving waters will be *negligible* and not significant as will the cumulative effects to fish and fish habitat.

4.3.2.11 Garbage and Other Waste

Solid nonhazardous waste will be compacted and transferred to shore. Sludges from oil-water separation units or other process vessels, spent lubricants, all plastic material, glass and metal wastes will be transferred to shore for appropriate handling. Toxic or hazardous waste will be transported to shore for appropriate disposal. There will be no interaction between garbage and marine biota.

4.3.2.12 Small Spills

Fuel and other chemicals will be transported to the FPSO and drill rig(s) by supply boat from onshore facilities. There could be occasional spillage of small quantities of these materials, during transfer to the FPSO. If static oil contained in the flow lines and risers was lost due to accidental rupture, a maximum of 1,400 to 3,100 m^3 of oil could be lost to the environment (from the volumes of liquids estimated for flow line testing).

Crude oil will be transferred from the FPSO to shuttle tankers. An offloading system will be provided. Crude oil would be pumped from the stern of the FPSO to the shuttle tanker. There is a potential for spillage and small accidents during crude oil transfer operations. Risk factors and effects of these spills are discussed in Chapter 5.

Mitigation

All crude oil transfers and fuel, chemical and waste-handling activities will be carried out in a manner designed to minimize or eliminate chronic inputs and accidents. Details about these activities will be provided in the EPP and operations manuals (see Chapters 6 and 8 for further details).

All subsea equipment will be routinely visually monitored by ROV. Procedures will be developed for simultaneous drilling and production operations that will address anchoring and dropped objects protection. The safety zone will be enforced by the standby vessel.

If a controlled disconnect is required because of a perceived unavoidable collision (iceberg, other vessel), all subsea facilities, including export lines, will be flushed and the oil circulated to the FPSO, all systems will be shut down and valves will be closed. Little, if any, crude oil would be released during a controlled disconnect. However, if an emergency disconnect were required, there would be an emergency shutdown and a potential for a loss of crude oil from the riser. The maximum volume contained in the riser is approximately 64 barrels of oil.

The FPSO will contain secondary containment systems and sumps designed to contain spills. Shutdown systems and routines will minimize environmental effects from accidental damage to the FPSO by isolating systems and equipment. Shutdown routines will be developed in the detailed design phase.

The EPP will contain detailed response measures for dealing with spills (see Chapter 6).

4.3.2.13 Atmospheric Emissions

During the production phase of the White Rose operation, there will be various activities that will generate atmospheric emissions. The sources of these emissions include:

- volatile organic compounds (VOC) from storage tank breathing and filling losses;
- combustion products (gases) used as an inerting blanket gas in the tanks;
- combustion products (NO_x, SO_x, CO, particulate matter (PM), unburned hydrocarbons and CO_2) from generators, turbines, helicopters and marine vessels; and
- flaring operations during well testing or in production upset conditions that emit combustion products.

Greenhouse Gas Emissions

While it is very early in the project to provide a definitive estimate of White Rose greenhouse gas emissions, an approximation can be given by scaling down the estimated Terra Nova emission of approximately 530,000 t/y of CO_2E for their 150,000 bopd FPSO and support equipment (see Table 4.3-13). Assuming that the White Rose project (100,000 bopd) may emit approximately 70 percent as much as Terra Nova gives an estimate of approximately 370,000 t/y. For comparison, Husky Oil's Gross Operated Greenhouse Gas Emissions from all of its Canadian operations were approximately 6.5 million t in 1998.

Storage tank emissions from the FPSO and the shuttle tanker are a result of VOC volatilization in the cargo due to heating (such as solar) and vessel agitation. These include breathing, working and standing storage losses and the quantity of emissions is dependent on the size, type and seals on the tank as well as the temperature of crude oil and number of turnovers.

VOC emissions are also a result of the loading and unloading of the tanks. The total loading loss is a result of displacement of vapours in an empty tank compartment before loading and evaporation during the loading process.

The VOC emissions can also be speciated according to Table 4.3-14 (JWEL 1998). The remaining percentage is made up of hydrocarbon (for example, methane, ethane, etc.) emissions.

Combustion (inerting) gases are used to generate a positive pressure difference in the tanks to prevent outside air from entering the tanks and mixing with the vapours. This prevents a potential hazardous situation from occurring such as risk of ignition and explosion/fire. Typically, the oxygen content in the inerting gas is maintained below 8 percent (typically 5 percent). On the FPSO, the inerting gas could be generated from diesel-power generators and recycled into the cargo tanks. On the shuttle tanker, the exhaust gases from the ship powerhouse are typically directed into the tanks. These gases would be vented, along with the VOCs, into the atmosphere to ensure the tanks are properly pressurized.

Another source of release of VOC and combustion gases will occur during the pumping of oil into the shuttle tanker empty tanks. The ship tank will usually be filled with combustion gases during the travel back to the FPSO to ensure no air enters the tank and to avoid an explosion. As the tanker is filled, these combustion gases will be displaced by the oil and released into the atmosphere.

Table 4.3-13 Estimated Greenhouse Gas Emissions of Terra Nova FPSO and Support Equipment

Emission Source	Consumption/ Throughput (te/yr)	Combustion Gasses				Volatized Gases		Annual Release as CO_2E
		CO_2 GWP: 1		N_2O GWP: 310		CH_4 CWP: 21		
		EF	Q	EF	Q	EF	Q	
1. Storage Tanks	*[design data used]*	---	2,095	---	Not Available	0.0000002	1.46 (31)	2,126
2. Offloading		---	---	---	---	0.000017	124 (2,604)	2,604[1]
3. Gas Turbines	*[design data used]*	---	463,737	---	38 (11,780)	---	58 (1,218)	476,735[2]
4. Ballast Tank Inert Gas		2.75	2,884	---	Not Available	---	Not Available	2,884
5. Key Services Generators	650 [at 5% uptime]	3.2	2,080 (2,080)	0.00022	0.1 (31)	0.00008	0.05 (1)	2,112[3]
6. Flaring	*No data before Study No routine flaring takes place*	---	---	---	---	---	---	---
7. Fugitive Emissions	Assumes 4% of total [at 70% CH_4]	---	---	---	---	---	6,886	6,886
8. Boilers	3.740 [at 1.870 x 2]	2.75	10,285 (10,285)	0.00022	0.8 (248)	0.00042	1.6 (34)	10,567
9. Support Ship	8,760 [5 MW engine]	3.2	28,032 (28,032)	0.00022	1.9 (589)	0.00027	2.4 (50)	28,671
10. Helicopter	120	3.2	384 (384)	0.00022	0.03 (9.3)	0.000087	0.01 (0.2)	393[4]
TOTAL CO_2E	**---**	**---**	**509,497**	**---**	**12,657**	**--**	**10,824**	**532,978**

EF = Emission Factor
Q = Quantity Released (te/yr)
NA = Not Available

[1] Assuming 100 loadings, at 960,000 barrels each
[2] Assumes constant usage of two 39 MW gas turbines [each run at 30 to 35 MW normal load] at 95% with a highly consistent fuel gas stream
[3] Assumes running two back-up 6.5 MW diesel-powered generators [to be run only during emergency or scheduled maintenance down-time of gas turbines]at a consumption rate of 190 g/kWh
[4] Assumes average fuel usage to be approximately 1,200 kg per return flight from St. John's

Source: Petro-Canada 1998

Table 4.3-14 Speciation of VOC Emissions

Speciation*	Percentage (%)
Ethylbenzene	0.0042
Toluene	0.35
Xylene	0.11
Cyclohexane	1.24
Hexane	3.14
Benzene	0.42
Naphthalene	0.0008
n-Octance	0.32
Total Octane	2.02

* Breakdown is for Hibernia crude.
Source: JWEL 1998

Combustion gases will also be released from the FPSO powerhouse which is expected to include gas-fired turbines and back-up diesel generators. The turbines are expected to run continuously and will burn fuel gas from the process stream. The diesel generators are used as emergency stand-by units which would be tested (typically) once a month. They would also be used when one of the gas-turbines is down for maintenance.

Flares, another source of emissions, are necessary for the safe operation of the FPSO because they allow built-up gases to be released safely and quickly in operational upset situations. As produced gas will normally be re-injected, flaring operations from the FPSO will be of short term duration if required during upset conditions only. When a flare smokes, this generally indicates incomplete or inefficient combustion. The flare combustion products will be a function of the type of flare used and its efficiency, as well as the type and amount of fuel used. Flaring will also occur during short-term well testing operations (a number of hours over a several day period) during the drilling of the production wells. Combustion gases will also be generated from the operation of shuttle tankers and helicopters.

In general, the emissions of harmful substances are likely to be small and not detectable outside the immediate vicinity of the FPSO. Overall, effects of atmospheric emissions on fish and fish habitat from all sources are deemed *negligible*. The potential effects of atmospheric emissions on human health are addressed in Appendix 4.A; Husky Oil's HS&E policy with respect to atmospheric emissions is indicated in Section 8.8.3.1.

Other Gaseous Emissions Estimates

In addition to greenhouse gas emissions, the FPSO will emit carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), VOCs and particulate matter.

The major emission sources for CO, NO_x, and SO_2 and particulate matter are the turbines, inert gas generators, boilers and flaring. Storage tank vents, offloading and fugitive emissions account for most of the methane and VOC emissions.

Total annual gas emissions estimates by Terra Nova for their 150,000 bopd project are CO (3,065 t); NO_x (859 t); SO_2 (2 t), CH_4 (2,439 t) and COC (321 t). It is reasonable to assume that White Rose estimates will be somewhere in the order of 70 percent of Terra Nova's. It is believed that particulate matter emissions will primarily result from the flare. Husky Oil will design the flare system to be as efficient as possible, will locate the flare stacks so as to direct flare emissions away from accommodations and, as described above, will minimize flaring.

4.3.2.14 Effects of Ships and Boats

It is anticipated that the FPSO will be supported by two vessels of up to 12,000+ HP with a bollard pull of 150 tonnes. These will be standard supply vessels in common use for offshore support work. There will be about one transit per week to the FPSO for resupply. The supply vessels will transport fuel, chemicals, fresh water, food and all the other material necessary for operation and maintenance of the FPSO. One vessel will remain near the FPSO on standby. As well, there may be a drill rig and attendant supply vessels on site during the initial operations phase.

Potential effects of the presence of ships and boats have been discussed in Section 4.3.1.17. All discharges from ships and boats, including sanitary and domestic waste will be treated as described above. Overall, effects of vessel discharges would be *negligible*. Potential effects related to underwater noise are discussed below.

4.3.2.15 Effects of Helicopters

Helicopters (Super Puma or equivalent) will be used to transport personnel and materials to and from the FPSO and the drill rig (if present). There will be approximately four to five round-trips per week to the FPSO. Effects of helicopters on the marine environment are mainly related to noise, discussed in the following Section (4.3.2.16).

4.3.2.16 Effects of Noise

Marine animals, including fish, are dependent upon the underwater acoustic environment. There is concern about potential negative effects caused by the introduction of man-made noise into the marine environment. The potential effects of underwater noise on fish were discussed in detail in Section 4.3.1.19. In that section, noise effects from stationary drilling rigs, from supply vessels, and from aircraft were considered. The principal underwater noise sources during production will be similar to those during project development; however the FPSO will be an additional source of noise.

Floating Production Facility

Development plans for White Rose call for an FPSO. Machinery will include diesel and gas generators, thrusters for propulsion, pumps, compressors, a crude oil separation and processing system, and life-support systems. Most of the production machinery will be above the waterline, but propulsion engines and some other machinery will be below.

Most studies on the effects of noise associated with production activities have been done using sounds emitted by bottom-founded production platforms or artificial islands. Production platforms supported by metal legs have all of the machinery above the waterline and transmit very little sound to the water. Production platforms and artificial islands are relatively quiet. Noise levels and characteristics of a ship-shaped monohull FPSO may be similar to those emitted by a semisubmersible drilling rig or a large drillship.

Fish in the immediate vicinity of the FPSO may hear the sound, but the well-known attraction of fish to offshore production facilities indicates that they do not react strongly, if at all, to noises associated with offshore production activities. Effects of noise on fish and fish habitat would be *negligible*.

Supply and Standby Vessels

The supply and standby vessels will likely be the loudest sources of underwater noise associated with the development, however the effects will be transitory and similar to other vessels using the area. It has been well-established that mobile noise sources have greater effects on marine animals than do stationary sources (Richardson et al. 1995). Also, the potential effects of the supply vessels cover a much larger area because of their mobility. The effects of underwater noise from the supply vessels are likely to be of more concern than from the FPSO or tankers.

The potential effects, including cumulative effects, on fish and fish habitat of underwater noise from supply vessels were reviewed in Section 4.3.1.19 and were considered *negligible* and not significant.

Helicopters and Fixed-Wing Aircraft

Helicopters will be used to ferry personnel to and from the FPSO and the drill rig (if present). It is likely that fixed-winged aircraft will be used for ice reconnaissance. These activities are the same as those that occur during development drilling. The potential effects of helicopter and fixed-wing aircraft were fully discussed in Section 4.3.1.18.

4.3.2.17 Shore-Based Facilities

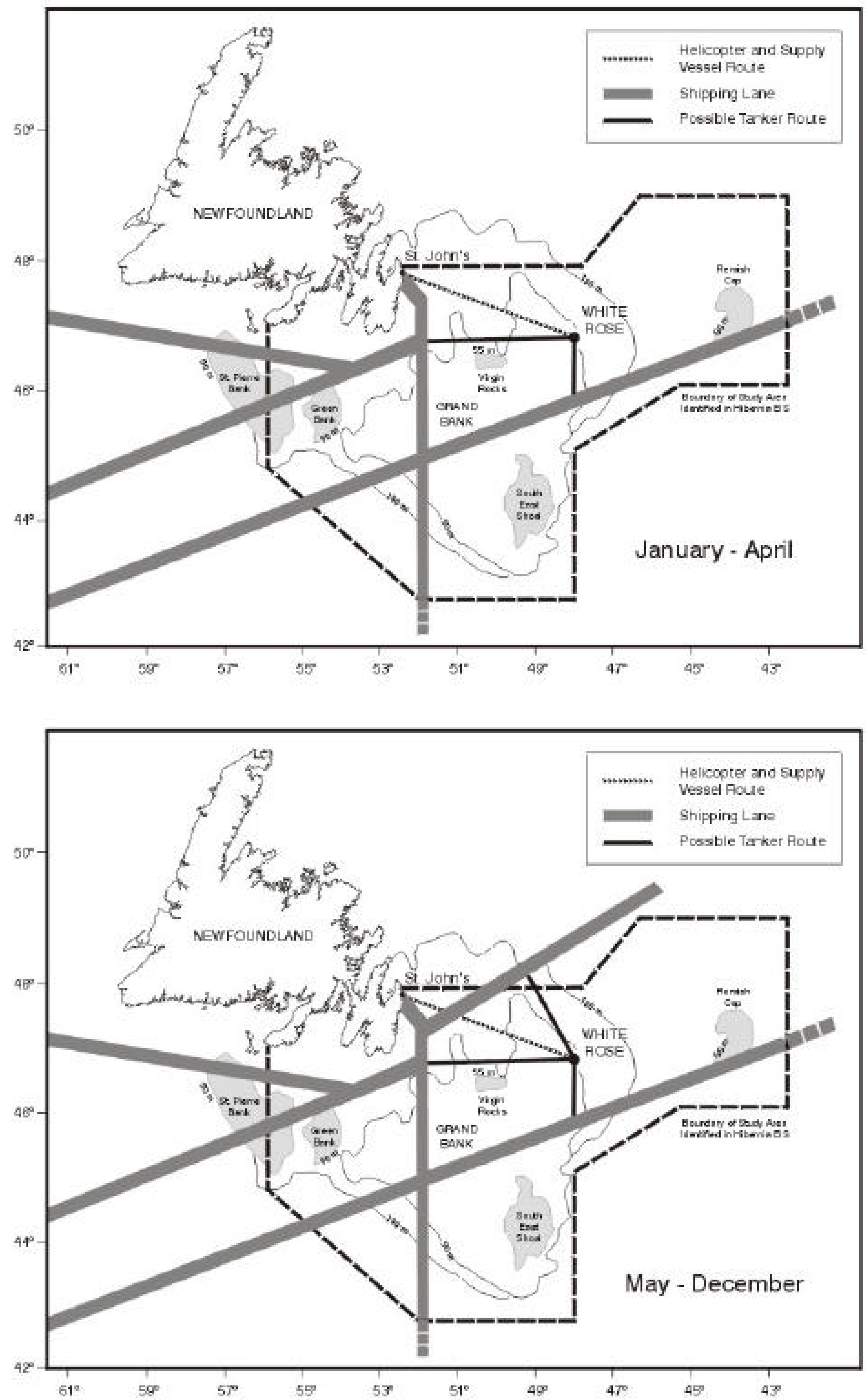
There will be no new shore based facilities required for the White Rose Development. Existing shore-based facilities will be used.

4.3.2.18 Transportation

Oil will be offloaded from the production facility to tankers for shipment. Up to three Canadian-flagged and crewed shuttle tankers of 80,000 to 135,000 t deadweight will be required. The number and size will depend on a number of factors, including the final design decisions and the location of markets for White Rose crude. Other factors notwithstanding, these tankers will be ice-strengthened and have double bottoms, double-sided hulls, segregated ballast, dual propulsion and advanced navigation and communication equipment. Each tanker will have a crew of 20 to 25.

The oil could be shipped directly to market or transshipped through an onshore storage and loading terminal. Final decisions on these transportation options will be made on the basis of a market analysis and consideration of other factors. General transportation routes are shown in Figure 4.3-5.

Figure 4.3–5 Transportation Routes Relevant to White Rose



1401-67.cdr 26JUN00 Figure 4.4-1

Source: adapted from Mobil (1985)

The transportation of the oil to the nearest shipping lanes will have a *negligible* and not significant effect on fish and fish habitat. Similarly, the cumulative effect of the incremental increase in addition to other traffic on the Grand Banks will be *negligible* unless there is a large oil spill (see Chapter 5).

4.3.3 Decommissioning

Interactions between decommissioning and abandonment activities and ecosystem elements are shown in Table 4.3-1.

When the White Rose oilfield has been depleted to a level where further production is uneconomic, the site will be abandoned and restored to minimize residual effects on the environment. Approvals to abandon components of the White Rose Development will be obtained in accordance with the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations*. The technology associated with abandonment and removal procedures is expected to change over the next 20 years, resulting in more efficient and effective techniques.

4.3.3.1 White Rose Development Area

Individual wells may either be abandoned as they become unproductive or at the end of the life of the field or, in the case of injection wells, when reservoir injection is no longer required. In general, well abandonment will consist of the following procedures:

- cement plugs and mechanical bridge plugs will be installed in the wells to seal the formation,
- the master valve assembly, upper tree structure, guide base, and flowline support structure and flowline will be removed; and
- production wells will be purged of hydrocarbons and abandoned in place.

Abandonment procedures will be prepared for the straightforward task of removing the FPSO. All hazardous topsides equipment will be decommissioned offshore prior to towing inshore. All anchors, anchor lines, and anchor chains will be retrieved.

Subsea facilities include the production manifolds, riser base manifolds, loading riser manifold, flowlines and export lines. Any subsea facilities installed above the seafloor will be purged of hydrocarbons and decommissioned in accordance with regulations in place at the time. All umbilicals will be decommissioned, made safe, and then retrieved. Any subsea facilities installed on the sub-seafloor will be purged of hydrocarbons and left in place.

Effects on Benthos

There will be some disturbance to infaunal communities during abandonment and decommissioning (see Table 4.3-1). Disturbance will be *low magnitude* (1), *short duration* (1) and *very localized* (1) (Table 4.3-10) and *not significant* (Table 4.3-11). Cumulative effects will be of similar nature and magnitude.

Effects on Biofouling Community

Effects on the biofouling community will vary depending upon the options available at the time of decommissioning. Where structures are removed the communities will be lost. The benthic community will return to predevelopment conditions. There is no associated effect. Where structures are not removed, biofouling communities will be maintained on these hard substrates as long as the structures are intact. While this effect (and cumulative effects) will be *continuous*, it will be *low magnitude* at most and *not significant*.

Effects on Fish

The most important effect on fish will be the termination of the no fishing safety zone, if in fact it constituted a refuge. Assuming a diverse commercial fishery operates in the area, conditions should revert to those before development. Overall there would be no adverse effect.

If some structures remain projecting above the seabed, there will be a *positive*, *low magnitude* (1) (at most), *very localized* (1), *continuous* effect on fish populations due to the reef effect (Table 4.3-10). Fish will be slightly protected from predation by bottom trawlers. On the other hand, there may be a *negative* effect (*very localized, negligible* to *low magnitude* but *continuous*) on the fish, if a groundfish fishery resumes in the area. Cumulative effects would be *additive* and of similar *magnitude, extent and duration*. All effects are rated *not significant* (Table 4.3-11).

4.3.3.2 Shore-Based Facilities

The shore-based facilities will be located in an existing port. As a result, cessation of White Rose and Hibernia and Terra Nova activities is expected to have *negligible* effects on the environment. Thus, both project and cumulative effects will be *negligible*.

4.3.4 Cumulative Effects Summary – Fish and Fish Habitat

Cumulative effects as defined by CEAA have been predicted in an integrated manner within the previous effects assessment sections. The various activities and attendant effects and potentially affected components of the fish and fish habitat VEC have been discussed in varying levels of detail depending upon the amount of available and useful information. This section provides a brief summary of those results.

Industrial activities evaluated for cumulative effects, included the following:

- White Rose (within project cumulative effects);
- Hibernia (an existing offshore oil development);
- Terra Nova (an impending offshore oil development);
- offshore oil exploration activity (seismic surveys and exploratory drilling);
- commercial fisheries (also see SEIS, Part Two); and
- marine transportation.

Criteria for inclusion of the above activities were that they have to be either ongoing or known to be imminent activities on the Grand Banks as defined by government application/registration processes. Major accidental events such as blowouts or tanker spills have not been included due to the low probabilities and large uncertainties in terms of timing, amounts, location, and so forth. It is recognized, however, that large spills/blowouts do have potential for significant effects and considerable emphasis will be placed on prevention, mitigation (including compensation) and monitoring (see Chapters 6, 7, and 8).

4.3.4.1 Offshore Oil Development

Most effects of offshore oil development activities (development, production, decommissioning) on fish and fish habitat have been predicted to be either *negligible* or, if effects occur, *not significant* (both Hibernia EIS and Terra Nova EIS as well as the present White Rose EIS).

Effects of White Rose activities of long duration (that is more than several years and in some cases for the life of the project) include those associated with:

- discharge of oily drill cuttings;
- produced water;
- noise of vessels, including FPSO, supply boats, and tankers on marine animals; and
- no fishing zone.

Produced water and oiled cuttings from White Rose will affect fish habitat but will not create a significant adverse effect on fish and fish habitat. For example, drill cuttings will occur mainly at the front end of the project, affect only benthic habitat, which may recover even before the middle phase (production) is complete. Similarly, produced water is mostly associated with the production phase and affects mainly the planktonic component of the ecosystem. Vessel noise is a characteristic of the first two phases but, for the most part, the effects on fish behaviour will be transitory; once the noise source (for example, a supply boat) moves on the fish will resume normal activity, if in fact it was disturbed in the first place. If the noise source is constant (for example, the FPSO), the fish will likely habituate. The no fishing zone is a positive cumulative effect on fish and fish habitat that will increase into the second phase of the project, depending upon the time it takes to create an artificial reef effect and a fish refuge, and the time it takes for the impacts to peak. Cumulative effects on fish and fish habitat from the different phases of White Rose (development, production, decommissioning) will occur but will be *not significant.*

With other oil developments, cumulative effects of White Rose will be additive but not overlapping and thus, effects will not magnify. Barring numerous catastrophic events, fish habitat will recover within a few years from any disturbance caused by oil development on the Grand Banks as it is presently envisaged.

The long-term effects of combined vessel noises from all of the oil developments on the behaviour of fish would have a *negligible* effect on population levels of fish.

The no fishing zones associated with offshore oil developments will positively affect fish but negatively affect the fishery in that there will be some exclusion areas (see Part Two). In the long term, these effects may cancel each other out or even have an overall *positive effect* (albeit *minor*) on fish stocks.

Husky Oil's philosophy in regard to cumulative effects assessment on the Grand Banks is that, given the present state of knowledge, comprehensive monitoring programs are warranted. It is Husky Oil's view that regional monitoring, in combination with other area operators, is the optimal approach. Monitoring and follow-up programs by Husky Oil and the other offshore operators will check the accuracy of EIS predictions, including cumulative effect predictions and respective ZOI, and provide feed back mechanisms for instituting additional mitigations, if required.

4.3.4.2 Commercial Fisheries

The commercial fisheries on the Grand Banks are diverse and extensive. Invertebrate target species include bottom-dwelling clams, scallops, crab and shrimp, as well as more pelagic species such as squid. Fish species include ground fish such as cod, flatfishes, skate, redfish; and pelagics such as capelin, tuna, shark, swordfish, and others. Harvesting techniques include dredges, rakes, bottom and midwater trawls, gill nets, longlines, traps, pots, and others. Hundreds of thousands of tonnes of high quality commercial fish, and associated bycatches, are harvested from the Grand Banks each year (see SEIS (Part Two) for detail). These harvests have contributed to significant effects on fish populations of the Grand Banks in the past as evidenced by the collapse of the northern cod. It is undoubtedly the goal of fisheries managers and scientists to manage the stocks in a sustainable manner for the future.

The cumulative effects of the various oil developments on the Grand Banks on fish populations will be additive, not magnified, and *negligible*. Relatively small numbers of fish eggs and larvae will be affected by development (for example, seismic) and production activities (for example, produced water discharge). Effects will be both sublethal and lethal although mostly undetectable. Assuming that the commercial fishery resource is managed in a sustainable manner by the resource agencies, the cumulative effect of the fishery and offshore development on fish and fish habitat will be not significant.

4.3.4.3 Marine Transportation

Hibernia, Terra Nova and White Rose will all have associated vessel traffic from supply boats and tankers. Other offshore exploration activity will also have associated drill rigs, supply boats, and seismic vessels. The movement of that incremental increase in vessel traffic into established shipping lanes has been considered.

A. Harvey and Company estimate that there will be an average of 25 vessel trips per month as a result of all oil operations on the Grand Banks (SEIS, Part Two). If Hibernia, Terra Nova and White Rose each averaged one tanker transit per week then overall tanker traffic would be on the order of 156 transits per year. Thus, total ship traffic for offshore oil development on the Grand Banks would be on the order of 676 vessel trips per year or about two vessels per day travelling on the Grand Banks.

To put the above in perspective, there were approximately 3,229 Canadian-bound international vessels transiting the Newfoundland ECAREG Zone in 1999, which is about normal for the area (W. Halley, pers. comm.). Of these, 406 were tankers. In addition, there were many thousands of transits by various sizes of fishing boats from long liners to trawlers (see SEIS (Part Two) for details) plus an unknown number of other domestic tankers and cargo ships.

It is clear from the above statistics that cumulative offshore oil activity on the Grand Banks will add an incremental amount of tanker traffic, at least relative to international tanker traffic presently on the Grand Banks. International vessel traffic is a concern because some vessels illegally discharge oily ballast in Canadian waters. However, Grand Banks oil developers will not add any oily waste because all tankers used by Hibernia, Terra Nova and White Rose will have segregated ballast tanks and will not discharge ballast in Canadian waters. If Grand Banks oil displaces international tanker traffic, including those that illegally deballast, then this could be viewed as a *positive* effect on the Grand Banks environment.

Overall cumulative vessel activity of Grand Banks oil developers on fish and fish habitat will be *negligible* and not significant, as will any effects of noise on fish. Total vessel traffic associated with all three developments and two drill rigs will probably comprise less than 25 percent of total international traffic on the Grand Banks and less than 3 percent when domestic vessels and fishing vessels are considered. White Rose, alone, is estimated to account for about 25 to 30 percent of the traffic associated with Grand Banks oil development.

4.3.5 Monitoring and Follow-up

Husky Oil will undertake an extensive EEM program to test the effects predictions and verify the modelling results presented in this document. It will be a statistically defensible program focused on the marine fish and fish habitat VEC. Husky Oil will conduct a thorough baseline characterization program in the summer of 2000, as per the White Rose Baseline Characterization Design document submitted to C-NOPB (Husky Oil 2000c). The EEM design will include both operational and accidental events programs. Testable hypotheses will be the basis for selection of candidate attributes and monitoring requirements. Husky Oil is discussing a regional monitoring program with both Hibernia and Terra Nova. The statistical design will allow a power analysis that distinguishes natural variation (noise) from project-specific effects (signal). One of the goals of Husky Oil's EEM program will be to link the results back to its environmental management system and make adjustments to procedures and practices where warranted. In addition, as per DFO's Policy for the Management of Fish Habitat, the fish habitat compensation plan requirements will be monitored. The EEM program is discussed further in Chapter 7.

4.4 MARINE BIRDS VEC

In the following sections, the potential effects of the White Rose development, production and decommissioning phases on marine birds are evaluated. Cumulative effects of the White Rose, Hibernia, and Terra Nova projects; offshore oil exploration (seismic surveys and exploration drilling); marine shipping and transportation; and commercial fishing activity are also considered. Each of the three oil development projects will have similar potential effects on marine birds of the Grand Banks.

4.4.1 Effects of Routine Development Operations (Drilling and Construction)

Potential interactions between development activities (as well as other projects and offshore activities) and marine birds are shown in sections A and D of Table 4.4-1. These interactions, potential effects, mitigation measures, monitoring approaches, and potential cumulative effects are discussed in the following sections. The environmental effects assessment the significance ratings of the predicted residual effects on marine birds during the development phase are summarized in Tables 4.4-2 and 4.4-3, respectively.

Table 4.4-1 Project-Environment Interaction Matrix for Marine Birds, Marine Mammals, and Sea Turtles

Valued Environmental Component: Marine Birds, Marine Mammals, and Sea Turtles					
Project Activities and Physical Works	**Marine Birds**	**Baleen Whales**	**Toothed Whales**	**Seals**	**Sea Turtles**
A. DEVELOPMENT PHASE					
Presence of Structures					
No Fishing Zone					
Subsea structures		X	X	X	X
Lights	X				
Flares	X				
Underwater Construction		X	X	X	X
Drilling Mud/Cuttings					
Water-based mud	X	X	X	X	X
Synthetic-based mud	X	X	X	X	X
Other Fluids and Solids					
Completion, packer and workover	X	X	X	X	X
Cement		X	X	X	X
BOP fluid	X	X	X	X	X
Hydrostatic testing fluid	X	X	X	X	X
Cooling water	X	X	X	X	X
Deck drainage	X	X	X	X	X
Bilge water	X	X	X	X	X
Sanitary and domestic wastes	X	X	X	X	X
Garbage					
Atmospheric Emissions	X				
Ships and Boats	X	X	X	X	X
Helicopters	X	X	X	X	X
Noise					
Drilling rigs	X	X	X	X	X
Support vessels	X	X	X	X	X
Helicopters	X	X	X	X	X
Shore Facilities [a]	N/A	N/A	N/A	N/A	N/A
Accidents (small spills)[b]	X	X	X	X	X
B. PRODUCTION PHASE					
Presence of Structures					
No Fishing Zone	X				
Artificial reef effect	X	X	X	X	X
Subsea structures		X	X	X	X
Surface structures	X	X	X	X	X
Lights	X				
Flares	X				
Underwater Maintenance		X	X	X	X
Injection Water	X	X	X	X	X
Produced Water	X	X	X	X	X
Storage Displacement Water					
Cooling Water	X	X	X	X	X
Deck Drainage	X	X	X	X	X
Bilge Water	X	X	X	X	X
Sanitary and Domestic Waste	X	X	X	X	X
Garbage					
Atmospheric Emissions	X				
Ships and Boats	X	X	X	X	X
Helicopters	X	X	X	X	X
Noise					
FPSO	X	X	X	X	X
Support vessels	X	X	X	X	X
Helicopters	X	X	X	X	X

Valued Environmental Component: Marine Birds, Marine Mammals, and Sea Turtles					
Project Activities and Physical Works	**Marine Birds**	**Baleen Whales**	**Toothed Whales**	**Seals**	**Sea Turtles**
Shore Facilities [a]	N/A	N/A	N/A	N/A	N/A
Accidents (small spills)[b]	X	X	X	X	X
Offshore Oil Spills [b]	X	X	X	X	X
C. DECOMMISIONING PHASE					
Offshore	X	X	X	X	X
Onshore[a]	N/A	N/A	N/A	N/A	N/A
D. OTHER PROJECTS AND ACTIVITIES					
Hibernia	X	X	X	X	X
Terra Nova	X	X	X	X	X
Oil Exploration					
Seismic surveys	X	X	X	X	X
Exploration drilling	X	X	X	X	X
Commercial Fisheries	X	X	X	X	X
Marine Transportation	X	X	X	X	X
Hunting	X				

Notes:
[a] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

Table 4.4-2 Environmental Effects Assessment for Marine Birds During the Development Phase

Valued Environmental Component: Marine Birds Phase: Development									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Presence of Structures									
No Fishing Zone	No Interaction		N/A						
Subsea structures	No Interaction		N/A						
Lights	Attraction (A)		Release stranded birds	1	2	6	3	R	1
Flares	Mortality (A)			1	2	1	3	I [a]	1
Underwater Construction	No Interaction		N/A						
Drilling Mud/Cuttings									
Water-based mud	Effects on health (A)	Recycle muds Treat and discharge cuttings		0	1	2	3	R	1
Synthetic-based mud	Effects on health (A)	Recycle muds Treat and discharge cuttings		0	1	2	3	R	1
Other Fluids and Solids									
Completion, packer and workover	Effects on health (A)	Recycle		0	1	2	3	R	1
Cement	No Interaction		N/A						
BOP fluid	Effects on health (A)	Recycle		0	1	2	3	R	1
Hydrostatic testing fluid	Effects on health (A)	Treatment		0	1	1	3	R	1
Cooling water	Effects on health (A)	Treatment		0	1	6	3	R	1
Deck drainage	Effects on health (A)	Treatment		0	1	2	3	R	1
Bilge water	Effects on health (A)	Treatment		0	1	2	3	R	1
Sanitary and domestic wastes	Nutrients (P); Increased predation (A)	Primary Treatment		1	2	6	3	R	1
Garbage	No Interaction		N/A						
Atmospheric Emissions	Effects on health (A)	Equipment Design		0	1	6	3	R	1
Ships and Boats [b]	Disturbance (A)		Avoid colonies	0	4	6	3	R	1
Helicopters [b]	Disturbance (A); Mortality (A)		Avoid colonies & repeated overflights of bird concentrations	1	4	4	3	R	1
Noise									
Drilling rigs	Disturbance (A)			0	2	6	3	R	1
Support vessels	Disturbance (A)		Avoid colonies	0	4	6	3	R	1

Valued Environmental Component: Marine Birds Phase: Development									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Helicopters	Disturbance (A); Mortality (A)		Avoid colonies & repeated overflights of bird concentrations	1	4	4	3	R	1
Shore Facilities [c]									
Accidents [d]									

KEY:

Magnitude:	**Geographic Extent:**	**Frequency:**	**Duration:**	**Reversibility:**	
0 = negligible	1 = <1 km²	1 = < 11 events/yr	1 = < 1 month	R = Reversible	[a] Effects on individuals irreversible but any population effects are likely reversible.
1 = Low	2 = 1-10 km²	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible	[b] Effects of noise considered here.
2 = Medium	3 = 11-100 km²	3 = 51-100 events/yr	3 = 13-36 months		[c] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
3 = High	4 = 101-1000 km²	4 = 101-200 events/yr	4 = 37-72 months		[d] Effects assessment of offshore spills is contained in Section 5.8.
	5 = 1001-10,000 km²	5 = >200 events/yr	5 = > 72 months		
	6 = >10,000 km²	6 = continuous			

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

Table 4.4-3 Significance of Predicted Residual Environmental Effects on Marine Birds During the Development Phase

Valued Environmental Component: Marine Birds				
Phase – Development	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Presence of Structures				
No Fishing Zone				
Subsea structures				
Lights	NS	1	3	2
Flares	NS	1	3	1
Underwater Construction				
Drilling Mud/Cuttings				
Water-based mud	NS	3	3	3
Synthetic-based mud	NS	3	3	3
Other Fluids and Solids				
Completion, packer and workover	NS	3	3	3
Cement				
BOP fluid	NS	3	3	3
Hydrostatic testing fluid	NS	3	3	3
Cooling water	NS	3	3	3
Deck drainage	NS	3	3	3
Bilge water	NS	3	3	3
Sanitary and domestic wastes	NS	2	3	2
Garbage				
Atmospheric Emissions	NS	3	3	3
Ships and Boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
Drilling rigs	NS	3	3	3
Support vessels	NS	3	3	3
Helicopters	NS	3	3	3
Shore Facilities[a]				
Accidents[b]				

KEY:

Residual Environmental Effect Rating:

S = Significant Adverse Environmental Effect

NS = Not-significant Adverse Environmental Effect

P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extend >100 km2 (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence

2 = Medium Level of Confidence

3 = High Level of Confidence

Probability of Predicted Effect Occurring: based on professional judgement

1 = Low Probability of Occurrence

2 = Medium Probability of Occurrence

3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement

1 = Low Level of Certainty

2 = Medium Level of Certainty

3 = High Level of Certainty

[a] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.

[b] Effects assessment of offshore spill is contained in Section 5.9.

4.4.1.1 Presence of Structures

The FPSO will only be onsite for a short period of time prior to First Oil, the end of the development phase as defined in this document. However, ships (including the semi-submersible drill rig) and boats involved in the development phase could potentially disturb marine birds. The potential effects of structures on marine birds are discussed in Sections 4.4.1.8 and 4.4.2.1.

4.4.1.2 Lights and Flares

There is concern that night-migrating and other night-active birds will be attracted to light sources on offshore facilities, and/or be incinerated by the gas flare. During the development phase, drilling rigs, supply and standby ships will carry navigation and warning lights, and working areas will be illuminated with floodlights. There may be some flaring by the semi-submersible drill rig during the development phase however they will be usually confined to short duration testing activities. Gas flaring also will produce light that may attract birds. However, the heat and noise generated by the flare may deter marine birds from the immediate area.

No studies have been conducted in the study area concerning the effects of night illumination and flaring from offshore drilling rigs/vessels on birds. Daily onsite monitoring of seabirds (mostly Leach's storm-petrels) found on the drilling rig and sighted near the Terra Nova site since May 1999 provides data on the occurrence of seabirds attracted to offshore structures (U. Williams pers. comm.). For instance, monitoring aboard a Terra Nova vessel for a three-week period during summer 1998 resulted in the recovery and release of all 52 storm-petrels that were encountered (U. Williams, pers. comm.). A recent report on bird attraction to offshore structures provides an updated literature review as well as recommendations, based upon consultation with individuals with scientific and industrial expertise, for future monitoring and mitigation (Montevecchi et al. 1999). The following discussion is an overview of information presented in reviews by LGL Ltd. prepared for Mobil (Thomson et al. 1999: *EA of Exploration Drilling Off Nova Scotia*) and Petro-Canada (1995: Terra Nova EIS) as well as in Montevecchi et al. (1999). The reader is referred to these reports for further detail.

Several studies of bird attraction to offshore oil structures have been conducted elsewhere. Published information is available for offshore oil fields in the North Sea (Bourne 1979; Sage 1979; Jones 1980; Tasker et al. 1986) and the Gulf of Mexico (Ortego 1978; Pulinch and Dellinger 1980; Aumann 1981), and for exploration drilling in the Bering Sea (Baird 1990). Field studies of seabird attraction to lights that were not related to offshore oil fields also have been conducted in the Hawaiian Islands (Reed et al. 1985; Reed 1987; Telfer et al. 1987; Day and Cooper 1995; Podolsky et al. 1998). Many other studies have related bird mortality to lighted towers and skyscrapers.

These studies reveal that several species of birds have been attracted at night to lights on offshore oil and gas platforms, especially during foggy or overcast conditions. These include seabirds as well as migrating landbirds. Birds can injure themselves either by flying into structures on the platform (Avery et al. 1978), or by flying into gas flares and dying (Bourne 1979; Sage 1979; Wood 1999). Some accounts also describe birds becoming disoriented and flying aimlessly about the lights for hours, consuming energy and being delayed in their foraging or migration. Also, disorientation apparently caused by lights from offshore supply vessels may increase the risk of predation. Wiese and Montevecchi (1999) reported that Leach's storm-petrels were attacked and may have been eaten by great black-backed gulls after the petrels were apparently confused by the lights of the supply vessels and the drilling platforms. Gas-flare kills of night-migrating landbirds have been reported in the North Sea (Sage 1979), but some authors consider that the numbers involved are usually low (Jones 1980).

There is concern with respect to nocturnal seabirds, particularly young storm-petrels (Sage 1979; Reed et al. 1985; Reed 1987; Telfer et al. 1987). Large colonies of nesting Leach's storm-petrels exist in or near the study area, and very large numbers of storm-petrels forage offshore in the study area. The period of greatest risk of attraction to offshore lights is in September, when birds are dispersing from nesting colonies and moving to offshore wintering grounds. Young-of-the-year birds appear to be more susceptible to light attraction than adults, but the extent of storm-petrel susceptibility is unclear.

Reasonable efforts will be made to allow seabirds found stranded on boats and other offshore structures to recover, and be released at night near minimal lighting, following the protocol developed by Williams and Chardine (1999). Any birds found near dawn will not be released until the following night. Project personnel will also be made aware of bird attraction to the lights on offshore structures. Additional possible mitigation measures are discussed in Chapter 6.

The presence of lights on drill rigs and supply boats would have a *low* effect within an approximate *10 km^2* area for the entire duration (*13 to 36 months*) of the development phase (Table 4.4-2). There would be *continuous* use of lights during darkness. Flaring would potentially have a *low* effect within an approximate *10 km^2* area for intermittent periods during the development phase (Table 4.4-2). As previously mentioned, it is unclear whether flaring causes the mortality of large numbers of seabirds (Table 4.4-3). The flare may incinerate some seabirds (Wood 1999) but any effects at the population level are probably reversible. In an independent study prepared for the CAPP, Montevecchi et al. (1999) concluded that bird mortality associated with the lights and flares of offshore oil platforms on the Grand Banks requires further study.

All vessels (supply vessels to oil sites, fishing vessels, and seismic vessels) and offshore structures in the study area will have navigation and warning lights. In some instances, work areas will be lit by floodlights. As discussed in the preceding paragraphs, some seabirds may be attracted to these lights and, consequently, become stranded on vessels, drill rigs, or other offshore structures. This may occur more frequently at the Hibernia, Terra Nova, and White Rose sites than, for example, near a seismic vessel, as illuminated areas will be larger and more intense on the drilling platforms. However, cumulative effects are not expected to exceed those expected for individual oil development sites. The sites are separated geographically so birds present in one area will not be attracted to the lights at another site. Effects will be additive with other oil developments but not overlapping and not synergistic; thus, effects will not magnify. Similarly, the cumulative effects from flaring at White Rose, Hibernia, and Terra Nova are not expected to exceed the rankings predicted for White Rose. There will be *no significant cumulative effects* of lights and flares on marine birds.

4.4.1.3 Discharge of Drilling Muds and Cuttings

Zone of Influence

A modelling study of potential depositional characteristics of drill cuttings produced by the White Rose Development was conducted by Seaconsult (Hodgins and Hodgins 2000). The results of that study, and the White Rose ZOI are discussed in detail in Section 4.3.1.4 and shown graphically in Figure 4.3-2.

Effects

Cuttings, and the oil or glycol discharged with them will have *negligible* effects on birds. Cuttings fall to the seafloor; therefore, there is little chance of interaction with birds on the surface.

As previously discussed (Section 4.3.1.4), drilling activities are unlikely to produce concentrations of heavy metals in muds and cuttings that will bio-accumulate and be harmful to seabirds (Neff et al. 1980 in Hinwood et al. 1994). A recent study on the effects of the synthetic drilling fluid N65DW (similar to IA fluid 35) on mallard ducklings, which had ingested the substance revealed that very high concentrations, higher than would be expected at an offshore oil site (M. Ferer, pers. comm.), were required to induce a physiological response (Gallagher et al. 1999). Some duckings experienced a slight reduction in body weight gain at concentrations of 5,620 ppm, but no mortalities were observed. Therefore effects will be *negligible* and not significant.

The cumulative effect of seabird exposure to drilling muds and cuttings from current drilling activities at Terra Nova, past drilling at Hibernia, and planned drilling at White Rose will be *negligible* and not significant. As previously stated, there is little chance seabirds will interact with muds and cuttings and because there is no plausible pathway for significant exposure, there is little chance that heavy metals will bioaccumulate to harmful levels.

4.4.1.4 Discharge of Other Fluids and Solids

The discharge of treated completion, packer, and workover fluids would have *negligible* effects on birds as hydrocarbon levels are reduced to very low levels, acids are neutralized, and small volumes of these fluids are released (see Section 4.3.1.5 for further details). Similarly, blowout preventor fluid will have *negligible* effects on seabirds because glycol-water mixes will be used and will have a low toxicity.

Periodic releases of small amounts of glycol will have *negligible* effect on marine birds. Also, potential effects of hydrostatic testing fluid will be *negligible* as the test fluids are immediately diluted upon release; if this occurs rapidly, none of its component chemicals are hazardous to seabirds (Black et al. 1994). Development drilling will require seawater, most of which will be used as cooling water. Effects on marine birds will be *negligible* because the volume of entrainment will be low and the area of thermal effects will be small.

Cooling water will be chlorinated to a level of 1 or 2 mg/L chlorine and discharged at temperatures of approximately 30°C above ambient. Effects on marine birds will be *negligible* because the volume will be low and the area of thermal effects will be small. There would be no interaction between the discharged cement piles and marine birds.

Other fluids containing treated oily water, like deck drainage and bilge water, may affect the health of seabirds (see Section 4.4.2) but because these substances will be treated (or diluted), recycled, or discharged below the water surface (see Section 4.3.1.5) the effect on seabirds will be *negligible* and not significant.

Although sanitary and domestic wastes will be treated before discharge (see Section 4.3.1.9), seabirds (most notably gulls) may be attracted to these potential food sources. An increase in gulls around the site may result in increased predation on smaller seabirds, like the Leach's storm-petrels, that associate with offshore structures (Wiese and Montevecchi 1999). If this event occurs, the number of smaller seabirds involved will likely be low and effects will be *low* within an approximate *10* km^2 area for the entire duration (*13-36 months*) of the development phase with greater than *200* sanitary and domestic waste discharges per year (Table 4.4-2). Since it is unlikely that these discharges will lead to an overall increase in gull populations, any increase in gull predation at the site is likely to be accompanied by decreases elsewhere.

The combined discharge of the fluids and solids from all offshore oil development sites on the Grand Banks will have the same potential effects rankings as those predicted for White Rose alone. The treatment of discharges will result in no significant cumulative effects. All tankers used by Hibernia, Terra Nova and White Rose will have segregated ballast tanks and/or will not discharge ballast in Canadian waters, minimizing any introduction of oil into the water surface.

4.4.1.5 Atmospheric Emissions

Although atmospheric emissions could, in theory, affect the health of some marine seabirds, the effects will be *negligible*, because emissions of potentially harmful materials will be small and they will rapidly disperse to undetectable levels (see Section 4.3.1.16).

Potential cumulative effects of atmospheric emissions released from the three oil development sites and their supply ships, seismic vessels, fishing vessels, and other ships in the study area will be *negligible* for marine birds. Emissions are not expected to be detectable beyond the immediate area of discharge, as they will rapidly disperse due to their volatility, temperature of emission and the exposed and often windy nature of the Grand Banks. Emissions will not accumulate to potential deleterious levels over the duration of the development phase.

4.4.1.6 Effects of Ships and Boats

Ships (including the semi-submersible drill rig) and boats could potentially affect birds through discharges, lights, flares (drill rig), physical presence of the structure, and noise. With the exception of noise and the physical presence of structures, potential effects of ships and boats have been discussed in previous sections and are summarized in Table 4.4-3. Potential effects related to noise and the physical presence of structures are discussed in Sections 4.4.1.8 and 4.4.2.1, respectively. A discussion of chronic releases from all vessel traffic and the associated cumulative effects is in Section 4.4.2.7.

4.4.1.7 Effects of Helicopters

Personnel and supplies will be transported to and from the drilling rig via helicopters (Super Puma class) with flights occurring approximately four to five times per week.

Potential effects of helicopters on the marine environment are mainly related to noise, which is discussed in the Section 4.4.1.8.

4.4.1.8 Effects of Noise

The normal offshore activities of ships are likely to have inconsequential effects on marine birds. Some species will be attracted to drilling rigs and ships/boats. Direct effects on other species are unlikely because seabirds are highly mobile and can easily avoid ships and drill rigs by flying or diving. Energy expended in these infrequent evasive movements would be trivial and would have no effect on an individual bird's daily energy budget.

Noise and disturbance from ships are unlikely to affect birds in the area. Birds have adapted to ship traffic throughout the world. Some species, such as northern fulmar and gulls, are attracted to ships and often follow them for extended periods (Wahl and Heinemann 1979; Brown 1986). Thus, noise and disturbance from normal offshore ship operations will not affect marine birds in offshore waters. Effects would be *negligible*.

There is a concern that passing ships could disturb seabird colonies. Cliff-nesting species are susceptible to panic caused by human activities. Temporary abandonment of colonies by adult birds can increase predation by gulls and ravens of unguarded eggs and young. This EIS identifies the locations of important colonies and the timing of their use by birds (see Section 3.9). Prudent seamanship dictates that the supply vessels will maintain adequate distances from any seabird colonies. A distance of 2 km will insure the safety of nesting seabirds. Therefore, there will be *negligible* effects on colonial marine birds.

Most marine birds flush or dive in response to low-flying aircraft (e.g., Polar Gas Project 1977; LGL Ltd., unpubl. data). The significance of these disturbances is probably low, if the flights are infrequent. In one of the few systematic studies of aircraft disturbance, Ward and Sharp (1974) found that moulting sea ducks in the Beaufort Sea showed no detectable reactions to helicopter overflights at 300 m above sea level. Overflights at 100 m had no apparent influence on overall feeding activity or population size, although the ducks did show short-term avoidance reactions.

Studies of other species in other situations have shown a variety of responses to overflying aircraft (Davis and Wisely 1974; Gollop et al. 1974a,b; Schweinsburg 1974; Koski 1975, 1977; Barry and Spencer 1976; Fyfe and Oldenorff 1976; Platt and Tull 1977; Fletcher and Busnel 1978; Webb 1980). In general, these studies support the contention that birds respond most to low level flights and that the effects of these responses are generally transitory.

Of most concern are large colonies of nesting seabirds. An aircraft flying near a seabird colony is capable of causing a panic response by the birds, which can result in eggs and flightless young being accidentally pushed off cliff ledges when the adults suddenly flush, or being unguarded and thus exposed to harsh weather and predators. The helicopters (and any fixed-wing aircraft potentially used for ice reconnaissance) used for the White Rose project will be based at the St. John’s airport and will generally fly “straight” to the White Rose site. Project aircraft will be directed to avoid the closest seabird colonies (such as, Witless Bay islands). Effects on birds at colonies would be *negligible*.

If for some reason aircraft have to detour from the normal direct route to and from White Rose, pilots will be instructed to avoid repeated overflights of concentrations of birds and/or important bird habitats (such as, colonies). Each aircraft will carry maps indicating the location of colonies. Guidelines for avoiding major seabird colonies will be based on Nettleship (1980). These Canadian Wildlife Service guidelines recommend that aircraft not approach closer than 8 km seaward and 3 km landward of a major seabird colony from 1 April to 1 November. The locations of seabird colonies and other areas where marine birds congregate are identified in this EIS (Section 3.9). During all flights, the helicopters and aircraft will fly at minimum altitudes of 600 m whenever possible. Effects of aircraft flying at 600 m or more on birds in open water would be *negligible*. However, when lower altitudes are necessary, such as during take-off and landing from the drill rig (or FPSO), birds in the area may be disturbed. Potential effects of aircraft at altitudes lower than 600 m would be *low*, within a *11-100* km^2 area for the entire duration of the development phase (*13-36 months*). There would be *101-200* flights per year of the development phase. For the majority of the time, aircraft will have *negligible* effects on birds, both at colonies and offshore.

Overall, acoustic effects on marine birds caused by the presence of drill rigs, support vessels, and aircraft would be *negligible* and not significant.

A discussion of noise levels from White Rose, Hibernia, Terra Nova, oil exploration, shipping and commercial fishing vessels is presented in Section 4.5.2.8. Cumulative effects from noise produced from these sources will have a *not significant effect* on seabirds. As previously discussed, seabirds are often attracted to offshore structures and vessels, and are usually not disturbed by industrial noise in air. Birds spend relatively small amounts of time underwater and are not expected to be affected by underwater noise, unless they dive within a few metres of the air guns towed by an operating seismic exploration vessel.

4.4.1.9 Shore-based Facilities

As existing shore-based facilities will be accessed, requiring no new facilities onshore.

The potential cumulative effects from the St. John's harbour facilities for White Rose, Terra Nova and Hibernia will be *negligible* for marine birds. The combined activities from these facilities will not exceed those commonly associated with normal harbour operations nor will cumulative effects increase the rankings predicted for White Rose alone.

4.4.2 Effects of Normal Production and Maintenance Operations

See Section 4.3.2 for an overview of the physical facilities and activities during production.

Potential interactions between production activities and marine birds are shown in section B of Table 4.4-1. These interactions, potential impacts, mitigation measures, monitoring approaches and potential cumulative impacts are discussed in the following sections. The environmental effects assessment and the significance ratings of the predicted residual effects on marine birds during the production and decommissioning phases are summarized in Tables 4.4-4 and 4.4-5, respectively.

Table 4.4-4 Environmental Effects Assessment for Marine Birds During Production (A) and Decommissioning (B) Phases

Valued Environmental Component: Marine Birds Phases: Production and Decommissioning									
Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Regulative Mitigation	Project Specific Mitigation	Evaluation Criteria for Assessing Environmental Effects					
				Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
A. PRODUCTION									
Presence of Structures									
No Fishing Zone	Increased food (P)			1	3	6	5	R	1
Artificial reef effect	Increased food (P)			1	2	6	5	R	1
Subsea structures	No Interaction		N/A						
Surface structures	Attraction (A); Mortality (A)		Release stranded birds	0-1	2	6	5	R	1
Lights	Attraction (A)		Release stranded birds	1	2	6	5	R	1
Flares	Mortality (A)			1	2	1	5	I [a]	1
Underwater Maintenance	No Interaction		N/A						
Injection Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Produced Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Storage Displace. Water	No Interaction		N/A						
Cooling Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Deck Drainage	Effects on health (A)	Treatment		0	1	2	5	R	1
Bilge water	Effects on health (A)	Treatment		0	1	2	5	R	1
Sanitary & Domestic Waste	Nutrients (P); Increased predation (A)	Primary Treatment		1	2	6	5	R	1
Garbage	No Interaction		N/A						
Atmospheric Emissions	Effects on health (A)	Equipment Design		0	1	6	5	R	1
Ships and Boats [b]	Disturbance (A)		Avoid colonies	0	4	6	5	R	1
Helicopters [b]	Disturbance (A); Mortality (A)		Avoid colonies & repeated overflights of bird concentrations	1	4	4	5	R	1
Noise									
FPSO	Disturbance (A)			0	2	6	5	R	1
Support vessels	Disturbance (A)		Avoid colonies	0	4	6	5	R	1
Helicopters	Disturbance (A); Mortality (A)		Avoid colonies & repeated overflights of bird concentrations	1	4	4	5	R	1

Valued Environmental Component: Marine Birds Phases: Production and Decommissioning									
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Evaluation Criteria for Assessing Environmental Effects**					
				Magnitude	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Shore Facilities [c]									
Offshore Oil Spills [d]	Mortality (A)		Contingency Plan						
B. DECOMMISIONING									
Offshore	Stop Disturbance (P); Reduce Mortality and Health Risks (P)			1	1	3	2	R	2
Onshore[c]									

KEY:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility:
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

[a] Effects on individual irreversible but any population effects are reversible.
[b] Effects of noise considered here.
[c] Not applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[d] effects assessment of offshore spills is contained in Section 5.9

Table 4.4-5 Significance of Predicted Residual Environmental Effects on Marine Birds During the Production and Decommissioning Phases

Valued Environmental Component: Marine Birds				
Phase – Development	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Probability of of Occurrence**	**Scientific Certainty**
A. PRODUCTION PHASE				
Presence of Structures				
No Fishing Zone	NS	3	3	3
Artificial reef effect	NS	3	3	3
Subsea structures				
Surface structures	NS	2	3	2
Lights	NS	2	2	2
Flares	NS	2	2	1
Underwater maintenance				
Injection water				
Produced water	NS	3	3	3
Storage displacement water				
Cooling water	NS	3	3	3
Deck drainage	NS	3	3	3
Sanitary and domestic waste	NS	2	3	2
Garbage				
Atmospheric emissions	NS	3	3	3
Ships and boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
FPSO	NS	3	3	3
Support vessels	NS	3	3	3
Helicopters	NS	3	3	3
Shore facilities [a]				
Offshore Oil Spills [b]				
B. DECOMMISIONING PHASE				
Offshore	P	3	3	3
Onshore[a]				

KEY:

Residual Environmental Effect Rating:

S = Significant Adverse Environmental Effect

NS = Not-significant Adverse Environmental Effect

P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extend >100 km² (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence

2 = Medium Level of Confidence

3 = High Level of Confidence

Probability of Predicted Effect Occurring: based on professional judgement

1 = Low Probability of Occurrence

2 = Medium Probability of Occurrence

3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement

1 = Low Level of Certainty

2 = Medium Level of Certainty

3 = High Level of Certainty

[a] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.

[b] Effects assessment of offshore spills is contained in Section 5.9

4.4.2.1 Presence of Structures

Seabirds are known to be attracted to offshore platforms, such as the FPSO that will be used during the operation phase of this project. The increased availability of food (*positive* effect) due to artificial reef and fishing zone effects (see Section 4.3.1.1) and a roosting area at sea may be the most important reasons why birds remain at offshore oil platforms following initial attractions (Montevecchi et al. 1999). Also, the discharge of human wastes at offshore platforms may attract birds (most notably gulls) in the same manner as nearshore sewage outlets. Although few studies have quantified the association of seabirds with offshore structures, higher densities of seabirds have been observed near platforms than in surrounding waters (Tasker et al. 1986; Baird 1990). Recent ship-based surveys between St. John's and the study area suggest that seabirds concentrate around offshore drilling platforms (Wiese and Montevecchi 1999).

Migrating birds nearing the end of their migration could be attracted to and land on offshore drilling and production platforms and supply boats. In the past, some concern has been expressed that these migrants could become stranded and die of exhaustion or lack of food and water, and that if the structures had not been present the birds would have made a landfall (Aumann 1981). This is primarily a concern for passerines (songbirds and perching birds), as seabirds that associate with offshore structures are readily able to survive at sea. The White Rose Development area is not within a major migration corridor for passerine birds. Any passerines in the area would be very much off course.

Gulls and terns are known to make extensive use of offshore structures for resting and feeding (Aumann 1981). Also, substantial numbers of shearwaters (mostly Greaters), smaller numbers of storm-petrels, and other seabirds have been observed from vessels at the Terra Nova site during May to September (see Table 3.9-7). It should be noted that there are many ships on the Grand Banks, and many of these are fishing boats that are more attractive to seabirds because they provide potential food in the form of fish refuse. The passive use of vessels/structures by resting gulls and terns would have *negligible* effects on these birds. The presence of gulls at offshore structures might lead to some predation on smaller birds. The effects are expected to be *negligible* to *low*, within a *10* km^2 area, and for the entire duration of the operation phase *(>72 months)* (Table 4.4-4). The physical presence of structures would have no significant effect on marine birds. Also, there is an increased risk of exposure to oil for seabirds that associate with offshore platforms as small spills can occur at these sites (Montevecchi et al. 1999). The potential effects of oil on seabirds is discussed in Section 5.9.1.2.

Overall, effects on marine birds caused by the physical presence of vessels and structures are expected to be *negligible*.

The physical presence of the FPSOs at White Rose and Terra Nova, the GBS at Hibernia, supply vessels and exploration drill rigs and seismic vessels within the study area during White Rose production phase would have a *not significant effect* on marine birds. Because effects are small around each structure, they will not be overlapping. Thus, they will be additive rather than synergistic and the cumulative effect is not significant.

4.4.2.2 Lights and Flares

The FPSO, supply and standby ships, and tankers will carry navigation and warning lights. Working areas will be illuminated with floodlights. The helideck on the FPSO will be floodlit and have omni-directional guidance lights. As discussed in Section 4.4.1.2, the presence of lights, including those on the FPSO, and supply boats would have *low* effects, within a 10 km^2 area for the entire duration of the operation phase (*>72 months*) (Table 4.4.-4). There would be *continuous* use of lights during darkness. Flaring would have a *low* effect within an approximate 10 km^2 area for intermittent periods during the operation phase (Table 4.4-4). As previously mentioned, it is unclear whether flaring causes the mortality of large numbers of seabirds (Table 4.4-5). The flare may incinerate some seabirds (Wood 1999) and these effects are irreversible but any effects at the population level are reversible. Husky Oil will record any mortalities due to collision with structures or the flare.

The appropriate mitigative measures described briefly in Section 4.4.1.2 will be employed during the operation phase of the White Rose project.

As discussed in Section 4.4.1.2, the cumulative effects of lights and flares from offshore oil structures and other vessels in the study area will be *not significant*.

4.4.2.3 Injection Water

A portion of the injected water may ultimately be discharged as produced water (see Section 4.4.2.4).

4.4.2.4 Produced Water

Zone of Influence

The White Rose ZOI model, using a 30,000 m^3/d discharge at a 5 m depth, (see Section 4.5.2.5) indicates an irregular ZOI ranging from a low of 1.8 km (a maximum estimate along the axis) in winter to an extreme of 3.6 km in the fall with the axis always trending southeast to southwest (Hodgins and Hodgins 2000). A detailed discussion of the produced water ZOI is in Section 4.3.2.5. It is noted that the modelling approach used to estimate the ZOI results in a very conservative estimate because 30,000 m^3/d is the maximum expected discharge at the peak of the field and because a good portion of the time the discharge will occur at a deeper depth (to 14 m when the FPSO is fully loaded), where vertical mixing will play a larger role.

Effects

Treated oily water contained in produced water is likely to have *negligible* effects on birds. The produced water plume will be narrow and snake like. Concentrations of 0.2 mg/L for at least one percent of the time are predicted to occur only within a few hundred metres of the FPSO. Birds may come into contact with the surficial sheen, however, it will be so dilute that it will not effect the thermoregulatory capability of the birds.

4.4.2.5 Other Operational Discharges

There will be little likelihood of oil-contaminated storage displacement water being discharged from the FPSO (see Section 4.3.2.7). As discussed in Section 4.4.1.4, cooling water will have *negligible* effects on marine birds and the effect of treated deck drainage and bilge water on seabirds will also be *negligible*. The discharge of sanitary and domestic wastes may attract gulls and lead to increased predation of smaller seabirds. As previously discussed, the number of smaller seabirds involved will likely be low and effects will be *low* within an approximate *10* km^2 area for the entire duration (>*72 months*) of the operation phase with greater than *200* sanitary and domestic waste discharges per year (Table 4.4-4). Since it is unlikely that these discharges will lead to an overall increase in gull populations, any increase in gull predation at the site is likely to be accompanied by decreases elsewhere.

As discussed in Section 4.4.1.4, the cumulative effects of discharges from offshore oil structures and vessels in the study area on marine birds will be not significant.

4.4.2.6 Atmospheric Emissions

Although atmospheric emissions could, in theory, affect the health of some marine birds, the effects will be *negligible*, because emissions of potentially harmful materials will be small and there will be rapid dispersion to undetectable levels (see Section 4.3.2.13).

As discussed in Section 4.4.1.5, the cumulative effects of atmospheric emissions from offshore oil structures and associated vessels, and other vessels (fishery, etc.) in the study area on marine birds will be *not significant*.

4.4.2.7 Effects of Ships and Boats

Potential effects of the presence of vessels are discussed in Section 4.4.2.1. All discharges from vessels, including sanitary and domestic waste will be treated as previously described. Overall, effects of vessel discharges on marine birds would be *negligible*. Potential effects related to underwater noise are discussed in Section 4.4.2.9.

Chronic Oil Pollution from Ship Discharge

Chronic and illegal discharge of oily bilge water off the southeast coast of Newfoundland appears to be getting worse. The Canadian Wildlife Service of Environment Canada has been conducting beach surveys of stranded birds for the last 16 years. These data are presently being analysed in an attempt to correlate the beached bird counts to tanker traffic; results will be published later this year (F. Wiese, pers. comm.). The study is presently being hampered by lack of good data on tanker traffic (F. Weise, pers. comm.).

Beach survey data from 1984 to 1997 indicate an increase of 3 percent per year in the percentage of oiled birds (Weise and Ryan 1999). The overall oiling rate of stranded birds is 70.98 percent with diving ducks and alcids (for example, common and thick-billed murres, Atlantic puffin, black guillemot, dovekie and razorbill) being the groups most affected (Weise and Ryan 1999). These species are most affected because they spend much of their time sitting on water or diving. The percentage of oiled birds on Newfoundland beaches is the highest reported worldwide (Weise and Ryan 1999; Lock and Deneault 2000).

Waters off the southeast coast of Newfoundland are a major junction for international tanker traffic designed for Canadian and U.S. ports. Analyses of the oil involved in bird strandings show that wastes are composed of mixtures of bunker C and marine diesel, indicating origins in the engine room bilges of ocean-going ships (Lock and Deneault 2000).

Implications for White Rose Oil Transportation

It is of concern that the percentage of oiled birds has been increasing when presumably government regulations; detection and enforcement have been improving in terms of rigor and technology. It is likely that the source of waste oil is the bilges of international tanker traffic and that unscrupulous operators illegally discharge this oil. This being the case, Husky Oil’s use of highly controlled domestic flag tankers will lower seabird mortalities if Husky Oil’s oil shipments displace international ones enroute to North American ports. Husky Oil vessels will not illegally discharge oily bilge water in Canadian waters.

4.4.2.8 Effects of Helicopters

Helicopters will be used to transport personnel and materials to and from the FPSO. There will be approximately five round-trips per week to the FPSO. Effects of helicopters on seabirds are mainly related to noise. These potential effects are discussed in the following section.

4.4.2.9 Effects of Noise

The potential effects of underwater noise on seabirds were discussed in detail in Section 4.4.1.8. In that section, noise effects from drill rigs, supply vessels, and aircraft were considered and potential effects would be the same in the operation phase. The principal underwater noise sources during production will be the same as those during project development, with the exception of noise produced by the FPSO. The noise produced from the FPSO (see Sections 4.3.2.16 and 4.5.2.8) will have *negligible* effects on seabirds; some species will be attracted to the light and some will avoid the noise of the FPSO (see Section 4.4.2.1). Direct effects on other species are unlikely because seabirds are highly mobile and can easily avoid the stationary FPSO. Energy expended in these infrequent evasive movements would be trivial and would have no effect on an individual bird's daily energy budget.

A discussion of noise levels from White Rose, Hibernia, Terra Nova, oil exploration, shipping and commercial fishing is presented in Section 4.5.2.8. Cumulative effects from noise produced from these sources will result in a *not significant* effect on marine birds.

4.4.2.10 Shore-based Facilities

No new shore based facilities are required for the White Rose Project. Existing shore-based facilities will be accessed.

As discussed in Section 4.4.1.9, the cumulative effects of activities at the shore-based facilities in the St. John’s harbour on marine birds will be *not significant*.

4.4.3 Decommissioning Phase

When the White Rose Field has been depleted to a level where further production is uneconomic, the site will be abandoned and restored to minimize residual effects on the environment. The technology associated with abandonment and removal procedures is expected to change over the next 20 years, resulting in more efficient and effective techniques. Therefore, exact decommissioning procedures will be finalized as the field approaches the abandonment phase. Interactions between decommissioning activities and marine birds are shown in section C of Table 4.4-1.

4.4.3.1 White Rose Development Area

Increased vessel activity during periods when facilities are being removed may cause some disturbance to seabirds over and above that associated with routine production activities. However, this disturbance will occur within relatively short periods of time and as discussed in Sections 4.4.1 and 4.4.2, will have *negligible* effects on birds. Abandonment of the White Rose site will probably have *positive* but still negligible effects on seabirds as potential disturbance, mortality, and health risks related to offshore operations will be eliminated. Similarly, the combined effect of abandonment at Terra Nova, Hibernia and exploration wells will have a *not significant* effect on seabirds.

4.4.3.2 Shore-based Facilities

No new shore-based facilities will be required for the White Rose Project. The shore-based facilities will be located in an existing port. The cumulative effect of the cessation of Terra Nova and Hibernia activities, in addition to White Rose will have a *not significant* effect on seabirds.

4.4.4 Cumulative Effect Summary – Marine Birds

One of the pressures on the populations of marine birds is legal and illegal hunting activity. Most of the Newfoundland salt water hunt involves murres (aka turres locally). They occur both offshore and inshore (see below) but are normally hunted inshore in small boats.

Thick-billed murres (*Uria lomvia*) comprise 95 percent of the murre species hunted by Newfoundlanders in coastal waters of the island (G. Robertson, pers. comm.). The majority of thick-billed murres breed in Greenland and the eastern Canadian Arctic and migrate south to winter on the Grand Banks. Some of these birds move into nearshore waters of Newfoundland as the winter progresses to probably forage or seek refuge from storms offshore (G. Robertson, pers. comm.). It is at this time that most murres are hunted. Only a portion of the population that is offshore and will interact with the project, will be subject to inshore hunting pressures.

The cumulative effects of the activities within each of the development, production and decommissioning phases of the White Rose project are expected to be *not significant* for marine birds. The cumulative effects of the entire White Rose project (all three phases combined) are also *not* expected to be *significant* for marine birds. The effects of most specific activities (discussed in each section) are predicted to be *negligible* and activities are expected to cause a *not significant effect* on marine birds. Mitigation measures and standard treatment of fluids and solids produced during all project phases will prevent significant effects on seabird populations within the study area during the entire project.

4.4.5 Monitoring and Follow up

Husky Oil conducted a supply vessel-based seabird monitoring program in conjunction with the 1999 drilling program and is continuing this program in 2000. Husky Oil will continue to review this program throughout the development phase of the project and, based on the program results, will make a decision as to whether to continue the monitoring program during the operation phase.

4.5 MARINE MAMMALS VALUED ENVIRONMENTAL COMPONENT

In the following sections, the potential effects of the White Rose development, production, and decommissioning phases on marine mammals are evaluated. Cumulative effects in consideration of Hibernia and Terra Nova are also considered.

4.5.1 Effects of Routine Development Operations (Drilling and Construction)

Potential interactions between development activities and marine mammals are shown in section A of Table 4.4-1. These interactions, potential effects, mitigation measures, and potential cumulative effects are discussed in the following sections. The environmental effects assessment and significance ratings of the predicted residual effects on marine mammals during the development phase are summarized in Tables 4.5-1 and 4.5-2, respectively. The following discussion of the marine mammal VEC is subdivided into baleen whales, toothed whales, and seals when expected effects differ among these groups.

4.5.1.1 Presence of Structures

Potential effects on marine mammals are mainly related to the effects of noise produced by offshore structures and activities. See Sections 4.5.1.7 and 4.5.1.8 for a discussion of this issue. There is a possibility that marine mammals may interact with subsea structures (see Section 4.3.1.1), but any effects would be *negligible*. Marine mammals generally habituate to stationary sources of noise and disturbance. Thus, the predictable noise and disturbance will have only local effects, at most. Thus, cumulative effects from the three development projects and the presence of some exploration drilling platforms and other vessels will be additive rather than synergistic, and are not significant.

4.5.1.2 Installation of Seabed Components and Underwater Construction

Marine mammals could potentially be affected by the noise associated with these activities (see Section 4.5.1.7). Potential effects of noise will be *negligible* to *low*, within a *10* km^2 area, for a period of less than *12 months*. The cumulative impacts of noise are discussed in Section 4.5.2.8.

Table 4.5-1 Environmental Effects Assessment for Marine Mammals During the Development Phase

Valued Environmental Component: Marine Mammals									
Phase: Development									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Presence of Structures									
No Fishing Zone	No Interaction		N/A						
Subsea structures	Disturbance (A)			0	1	6	3	R	1
Lights	No Interaction		N/a						
Flares	No Interaction		N/A						
Underwater Construction	Disturbance (A)			0-1	1-2	2	2	R	1
Drilling Mud/Cuttings									
Water-based mud	Effects on health (A)	Recycle mud Treat and discharge cuttings		0	1	2	3	R	1
Synthetic-based mud	Effects on health (A)	Recycle mud Treat and discharge cuttings		0	1	2	3	R	1
Other Fluids and Solids									
Completion, packer and workover	Effects on health (A)	Recycle		0	1	2	3	R	1
Cement	Increased food (P)			0					
BOP fluid	Effects on health (A)	Recycle		0	1	2	3	R	1
Hydrostatic testing fluid	Effects on health (A)	Treatment		0	1	1	3	R	1
Cooling water	Effects on health (A)	Treatment		0	1	6	3	R	1
Deck drainage	Effects on health (A)	Treatment		0	1	2	3	R	1
Bilge water	Effects on health (A)	Treatment		0	1	2	3	R	1
Sanitary and domestic wastes	Effects on health (A)?	Primary Treatment		0	1-2	6	3	R	1
Garbage	No Interaction	Transport to Shore							
Atmospheric Emissions	No Interaction		N/A						
Ships and Boats [a]	Disturbance (A)		Avoid conc. of mar. mamm.; maintain steady course & speed when possible	1	3-4	6	3	R	1

Valued Environmental Component: Marine Mammals									
Phase: Development									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Helicopters [a]	Disturbance (A)		Fly at min. altitude of 600 m whenever possible	1	1-3	4	3	R	1
Noise									
Drilling rigs	Disturbance (A)			0-1	1-2	6	3	R	1
Support vessels	Disturbance (A)		Avoid conc. of mar. mamm.; maintain steady course & speed when possible	1	3-4	6	3	R	1
Helicopters	Disturbance (A)		Fly at min. altitude of 600 m whenever possible	1	1-2	6	3	R	1
Shore Facilities [b]									
Accidents [c]									

KEY:

Magnitude:	**Geographic Extent:**	**Frequency:**	**Duration:**	**Reversibility:**
0 = Negligible	1 = <1 km²	1 = < 11 events/yr	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km²	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km²	3 = 51-100 events/yr	3 = 13-36 months	
3 = High	4 = 101-1000 km²	4 = 101-200 events/yr	4 = 37-72 months	
	5 = 1001-10,000 km²	5 = >200 events/yr	5 = > 72 months	
	6 = >10,000 km²	6 = continuous		

Ecological/Socio-cultural and Economic Context:

1 = Relatively pristine area or area not adversely affected by human activity.

2 = Evidence of existing adverse effects.

[a] Effects of noise considered here.

[b] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be required

[c] Effects assessment of offshore spills is contained in Section 5.9

Table 4.5-2 Significance of Predicted Residual Environmental Effects on Marine Mammals During the Development Phase

Valued Environmental Component: Marine Mammals				
Project Activity	Significance Rating	Level of Confidence	Likilihood	
	Significance of Predicted Residual Environmental Effects		Probability of Occurrence	Scientific Certainty
PHASE: DEVELOPMENT				
Presence of Structures				
No Fishing Zone				
Subsea structures	NS	3	3	3
Lights				
Flares				
Underwater Construction	NS	3	3	3
Drilling Mud/Cuttings				
Water-based mud	NS	3	3	3
Synthetic-based mud	NS	3	3	3
Other Fluids and Solids				
Completion, packer and workover	NS	3	3	3
Cement	NS	3	3	3
BOP fluid	NS	3	3	3
Hydrostatic testing fluid	NS	3	3	3
Cooling water	NS	3	3	3
Deck drainage	NS	3	3	3
Bilge water	NS	3	3	3
Sanitary and domestic wastes	NS	3	3	3
Garbage				
Atmospheric Emissions				
Ships and Boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
Drilling rigs	NS	3	3	3
Support vessels	NS	3	3	3
Helicopters	NS	3	3	3
Shore Facilities[a]				
Accidents[b]				

KEY:

Residual Environmental Effect Rating:
S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extend >100 km2 (4 or greater rating).

Level of Confidence in Effect Prediction:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of predicted effect occurring, based on professional judgement
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

[a] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9.

4.5.1.3 Discharge of Drilling Muds and Cuttings

Zone of Influence

A modelling study of potential deposition characteristics of drill cuttings produced by the White Rose Development was conducted by Seaconsult (Hodgins and Hodgins 2000). This study was detailed in Section 4.3.1.4. In general, conclusions that can be drawn from the White Rose modelling of cuttings depositions are consistent with Hibernia and Terra Nova that the biological effects ZOI will be limited to 500 m.

Effects

Drilling activities are unlikely to produce concentrations of heavy metals in muds and cuttings (see Section 4.3.1.4) that are harmful to marine mammals (Neff et al. 1980 in Hinwood et al. 1994). Effects will be *negligible* and not significant.

The cumulative effect of marine mammal exposure to drilling muds and cuttings from current drilling activities at Terra Nova, past drilling at Hibernia, and planned drilling at White Rose and other future sites within the study area will be *negligible*. As previously stated, heavy metals in muds and cuttings are unlikely to bioaccumulate to harmful levels.

4.5.1.4 Discharge of Other Fluids and Solids

The discharge of treated completion, packer, and workover fluids would have a *negligible* effect on marine mammals as hydrocarbon levels are reduced to very low levels, acids are neutralized, and small volumes of these fluids are released (see Section 4.3.1.5 for further details). Similarly, blowout preventor fluid will have negligible effects on marine mammals because glycol-water mixes will be used and will have a low toxicity. Periodic releases of small amounts of glycol will have a *negligible* effect on marine mammals. Also potential effects of hydrostatic testing fluid will be *negligible* as the test fluids are immediately diluted upon release; even if discharge occurs rapidly, none of the component chemicals are hazardous to marine mammals (Black et al. 1994). Development drilling will require seawater, most of which will be used as cooling water. Cooling water will be chlorinated to a level of 1 or 2 mg/L chlorine and discharged at temperatures of approximately 30°C above ambient. Effects on marine mammals will be *negligible* because the volume will be low and the area of thermal effects will be small. Cement piles will act as an artificial reef, and be colonized by epifaunal animals and attract fish (Section 4.3.1.5). The effects (either negative or positive) of the cement on marine mammals would be *negligible*.

The effects rankings for the combined discharge of the fluids and solids from all offshore oil development sites on the Grand Banks will be the same as those predicted for White Rose alone; effects will be *negligible*. The treatment of discharges and the relatively high tolerance level of marine mammals to hydrocarbons will result in a *not significant* cumulative effect.

Treated oily-water discharge from other drilling fluids, deck drainage, and bilge water could affect marine mammals. However, the marine mammals of the Newfoundland region rely on blubber rather than fur for insulation and are less likely to be affected by exposure to oily-water (see Section 5.9.1.3). Releases of treated oily water are likely to have *negligible* effects on marine mammals. Organic matter from sanitary and domestic wastes will be quickly dispersed and degraded by bacteria. The effects on marine mammals swimming in the receiving waters containing this small amount of organic matter and nutrients will be *negligible*.

4.5.1.5 Effects of Ships and Boats

Discussion of discharges from the vessels are included in the previous paragraphs. All discharges from vessels, including sanitary and domestic waste and bilge water will be treated, as described above. Overall, effects of vessel discharges on marine mammals would be *negligible.* Potential effects related to noise are discussed in the following sections.

4.5.1.6 Effects of Helicopters

Potential effects of helicopters on marine mammals are mainly related to noise, which is discussed in the following section.

4.5.1.7 Effects of Noise

This section presents information on the reactions of marine mammals to noises of the kind associated with the White Rose Development.

Materials will be transported to the drill rig by supply vessels. The boats will make approximately three visits per week. A dedicated stand-by vessel will also attend the rig throughout the drilling operation. Personnel will be transported to and from the drilling rig via helicopters with flights occurring approximately five times per week. Noise does not transmit well from air to water and so effects of helicopter overflights are mainly related to disturbance of seabirds, seals that are hauled-out on shore, and marine mammals that are directly under the flight path of the helicopter (see Sections 4.4 and 4.5).

Because underwater noise propagates for long distances, the potential zone of influence around a particular vessel can be many tens of kilometres in radius. The zone of influence of underwater noise at White Rose includes zones around the development area, shipping routes between the supply base and the drilling rig or FPSO, and the helicopter flight routes between St. John's Airport and White Rose.

Marine mammals depend on the underwater acoustic environment. Thus, the potential negative effects caused by human-made noise within the marine environment are a concern. The Terra Nova EIS (Petro-Canada 1995) provides a good review of the effects of noise associated with offshore oil development on marine mammals and the reader is referred to this document. The present section provides an overview of the Terra Nova EIS noise/marine mammal discussion (Petro-Canada 1995) with appropriate updates.

Because underwater noise propagates for long distances, the potential ZOI around a particular noise source can be many tens of kilometres in radius. The ZOI of underwater noise at White Rose includes zones around the development area, shipping routes between the supply base and the drilling rig or FPSO, and the helicopter flight routes between St. John's Airport and the White Rose oilfield.

Marine mammals typically are more tolerant of fixed location noise sources, like the semi-submersible drill rig and FPSO planned for use in the White Rose development, than moving sources.

Ringed seals were often seen near drillships drilling in the Arctic in summer and fall (several reports summarized by Richardson et al. 1995:282). Ringed seals and bearded seals approached and dove within 50 m of a projecter transmitting drilling noise into the water. More recent studies of seals near active seismic vessels (for example, Moulton and Lawson 2000) confirm that seals are tolerant of offshore industrial activities. Evidence from harbour seals in southern British Columbia also demonstrates that seals have a propensity to habituate to human activities.

Belugas, dolphins, and other toothed whales show considerable tolerance of drill rigs and their support vessels, particularly when there are not negative consequences from close approach to the activities (Richardson et al. 1995).

Baleen whales exhibit variable reactions (avoidance response in relation to distance from the noise source) to noise created by drilling rigs, but these reactions are likely related to the received sound level of the noise source. Some baleen whales are less responsive to noise, and habituation may occur, so that in time, whales may occur closer to drilling structures (for example, bowhead whales in Richardson et al. 1985a; 1995; 1990). Behavioural reactions would be limited to a very small area (a few 100 m) around a semi-submersible rig because noise levels are low (Richardson et al. 1995).

Effects of drilling operations on whales and seals may be *negligible* to *low*, *within a 10* km^2 area, and will continue throughout the drilling phase of the Project. Although the effects of each well location would be approximately *3 months*, the effects of all drilling is considered to be longer *(*between *37* to *72 months)* since drilling in the fairly restricted field area will likely continue into the production phase for several years. Because the drilling activities will continue for several years, habituation may occur, thereby reducing effects to *negligible*. Semi-submersible drilling rigs are quieter than drillships, and this "quieter" structure will likely be used in the White Rose project. Mitigation is not warranted because predicted effects are not significant. Overall, noise from drilling operations will have no significant effects on marine mammals.

Baleen whales may show little reaction or slow, inconspicuous avoidance reactions to boats and supply vessels that are moving slowly on a steady course. If the vessel changes course and/or speed, whales likely will swim rapidly away. Avoidance is strongest when the vessel travels directly toward the whale.

Dolphins may tolerate and often approach vessels of all sizes and ride the bow and stern waves (Shane et al. 1986). At other times, the dolphin species known to be attracted to boats will avoid them. This avoidance is often linked to previous boat-based harassment of the animals (Richardson et al. 1995). Other toothed whale species avoid boats. Generally, small cetaceans avoid vessels when they are approached within 0.5 to 1.5 km, with some species showing avoidance at distances of up to 12 km (Richardson et al. 1995).

The available evidence on the reactions of seals to boats indicates that seals in the water are quite tolerant of infrequent passage by boats, however, effects on the seals are generally unknown (Richardson et al. 1995).

The potential effects on baleen whales of individual passages by supply vessels during offshore operations are likely to be *low*, within a *101-1,000* km^2 area, and *<1 month* in duration. However, as there will be repeated passages, the effects from supply vessels are likely to be *low*, within a *101-1,000* km^2 area, and will occur for the entire duration (*13-36 months*) of the development phase. Effects on toothed whales and seals may be similar; that is, *low*, within a *101-1,000* km^2 area, and will occur for the entire duration (*13-36 months*) of the development phase. Effects on mammals can be reduced if the boats maintain a steady course and speed whenever possible and if areas with large numbers of whales are avoided.

Pinnipeds hauled out for pupping or moulting are very sensitive to aircraft disturbance (Richardson et al. 1995). It is highly unlikely that there will be overflights of seals that are pupping or moulting as few, if any, seals will be hauled out (either on ice or land) along the flight route to White Rose during these critical times or at other times of the year (Section 3.9). There will be ice scouting north of the study area by fixed-wing aircraft. Pilots of the ice patrol aircraft will be directed to maintain altitude during those sensitive pupping and moulting periods.

Toothed whales show variable reactions to aircraft overflights; some dive or swim away, while others exhibit no reaction (see Petro-Canada 1995). Some baleen species, like minke, bowhead and right whales reacted to aircraft overflights at altitudes of 150 to 300 m by diving, changing dive patterns or leaving the area (Leatherwood et al. 1982; Watkins and Moore 1983; Payne et al. 1983; Richardson et al. 1985b; 1985c).

Low flying helicopters and fixed-wing aircraft could cause *low* magnitude effects on marine mammals in the water within a *101 to 1,000 km^2* area, and these effects would occur intermittently (less than 200 flights per year) throughout the development phase (*13-36 months*). Any effects on seals hauled out on ice or land would be *low*, within a *101-1,000 km^2* area, and would rarely occur, as few seals haul out along the flight route between White Rose and St. John's. Helicopters will fly at a minimum altitude of 600 m whenever possible. Aircraft will be prohibited from flying low over wildlife in order for passengers to "get a better look" or for photography. With these measures in place, there will be *negligible* effects on marine mammals.

The potential cumulative noise sources and effects are discussed in Section 4.5.2.8.

4.5.1.8 Shore-based Facilities

There will not be any new onshore facilities required. Exisiting infrastructure will be used.

The potential cumulative effects from the St. John's harbour facilities for White Rose, Terra Nova and Hibernia will be *negligible* for the few seals that may occur in the harbour. The combined activities from these facilities will not exceed those commonly associated with normal harbour operations nor will cumulative effect rankings increase those predicted for White Rose.

4.5.2 Effects of Normal Production and Maintenance Operations

See Section 4.3.2 for an overview of the physical facilities and activities during production and maintenance operations.

Potential interactions between production activities and marine mammals are shown in section B of Table 4.4-1. These interactions, potential effects, brief mitigation measures, and potential cumulative effects are discussed in the following sections. The environmental effects assessment and the significance ratings of the predicted residual effects on marine mammals during the production and decommissioning phases are summarized in Tables 4.5-3 and 4.5-4, respectively.

Table 4.5-3 Environmental Effects Assessment for Marine Mammals During Production (A) and Decommissioning (B) Phases

Valued Environmental Component: Marine Mammals									
Phases: Production and Decommissioning									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
A. OPERATION									
Presence of Structures									
No Fishing Zone	No Interaction		N/A						
Artificial reef effect	Increased food (P)			1	1	6	5	R	1
Subsea structures	Disturbance (A)			0	1	6	5	R	1
Surface structures	Disturbance (A)			0	1	6	5	R	1
Lights	No Interaction		N/A						
Flares	No Interaction		N/A						
Underwater Maintenance	Disturbance (A)			0	1	1	1	R	1
Injection Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Produced Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Storage Displacement Water	No Interaction		N/A						
Cooling Water	Effects on health (A)	Treatment		0	1	6	5	R	1
Deck Drainage	Effects on health (A)	Treatment		0	1	6	5	R	1
Bilge water	Effects on health (A)	Treatment		0	1	6	5	R	1
Sanitary and Domestic Waste	Effects on health (A)?	Primary Treatment		0	1-2	6	5	R	1
Garbage	No Interaction		N/A						
Atmospheric Emissions	No Interaction		N/A						
Ships and Boats [a]	Disturbance (A)		Avoid conc. of mar. mamm.; maintain steady course & speed when possible	1	3-4	6	5	R	1
Helicopters [a]	Disturbance (A)		Fly at min. altitude of 600 m whenever possible	1	1-3	4	5	R	1
Noise									
FPSO	Disturbance (A)			1	1-2	6	5	R	1
Support vessels	Disturbance (A)		Avoid conc. of mar. mamm.; maintain steady course & speed when possible	1	3-4	6	5	R	1
Helicopters	Disturbance (A)		Fly at min. altitude of 600 m whenever possible	1	1-3	4	5	R	1

Valued Environmental Component: Marine Mammals									
Phases: Production and Decommissioning									
				Evaluation Criteria for Assessing Environmental Effects					
Project Activity	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Shore Facilities[b]									
Offshore Oil Spills[c]	Effects on health (A)								
B. DECOMMISIONING									
Offshore	Stop Disturbance (P); Reduce Mortality and Health Risks (P)			1	1	3	3	R	2
Onshore[b]									

KEY:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility:
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

[a] Effects of noise considered here.
[b] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used
[c] Effects assessment of offshore spills is contained in Section 5.9

Table 4.5-4 Significance of Predicted Residual Environmental Effects on Marine Mammals During Production and Decommissioning Phases

Valued Environmental Component: Marine Mammals				
Phase – Development	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Project Activity	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
A. PRODUCTION				
Presence of Structures				
No Fishing Zone				
Artificial reef effect	NS	3	3	3
Subsea structures	NS	3	3	3
Surface structures	NS	3	3	3
Lights				
Flares				
Underwater maintenance	NS	3	3	3
Injection water				
Produced water	NS	3	3	3
Storage displacement water				
Cooling water	NS	3	3	3
Deck drainage	NS	3	3	3
Bilge water	NS	3	3	3
Sanitary and domestic waste	NS	3	3	3
Garbage				
Atmospheric emissions				
Ships and boats	NS	3	3	3
Helicopters	NS	3	3	3
Noise				
FPSO	NS	3	3	3
Support vessels	NS	3	3	3
Helicopters	NS	3	3	3
Shore facilities[a]				
Offshore Oil Spills[b]				
B. DECOMMISIONING				
Offshore	P	3	3	3
Onshore[a]				

KEY:

Residual Environmental Effect Rating:
S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extend >100 km2 (4 or greater rating).

Level of Confidence:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence
[a] See Section 5.9

Probability of Occurrence: based on professional judgement
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

[a] Not Applicable. There will not be any new onshore facilities required. Existing infrastructure will be used.
[b] Effects assessment of offshore spills is contained in Section 5.9

4.5.2.1 Presence of Structures

Potential effects of structures (stationary platforms) on marine mammals are mainly related to the effects of noise produced by offshore structures. See Section 4.5.2.8 for a discussion of this issue. Potential effects of the physical presence of subsea structures on marine mammals will be *negligible*.

Cumulative effects from the FPSOs at White Rose and Terra Nova, and the GBS at Hibernia are mainly related to the effects of noise (Section 4.5.2.8). The cumulative effect of the physical presence of the structures on marine mammals will be *negligible*.

4.5.2.2 Artificial Reef Effect

The increased availability of food due to artificial reef effects (see Section 4.3.1.1) may attract marine mammals to the area but any effects will be *negligible*.

4.5.2.3 Maintenance of Subsea Structures

As previously mentioned, subsea structures will require periodic inspection, cleaning to remove fouling organisms, repairs, and maintenance of corrosion-protection devices and coatings. Maintenance activities will disturb a small area of the bottom and cause *negligible* and not significant effects on marine mammals.

The associated noise and disturbance of this maintenance activity could also cause potential effects on marine mammals. Effects of underwater noise, including cumulative effects, are discussed in Section 4.6.2.8. These effects will be *negligible*.

4.5.2.4 Injection Water

Any discharges of treated oily water from produced water at White Rose are likely to have *negligible* effects on marine mammals, because marine mammals are relatively unaffected by small amounts of oil (Section 5.9.1.3). Similarly, cumulative effects from discharges of produced water at Hibernia and Terra Nova are likely to be *negligible*.

4.5.2.5 Produced Water

Zone of Influence

The White Rose ZOI model, using a 30,000 m^3/d discharge at a 5 m depth (see Section 4.3.2.5), indicates an irregular ZOI ranging from a low of 1.8 km (a maximum estimate along the axis) in winter to an extreme of 3.6 km in the fall with the axis always trending southeast to southwest (Hodgins and Hodgins 2000). It is noted that the approach used to estimate the ZOI gives very conservative estimates because 30,000 m^3/d is the maximum expected discharge at the peak of the field and because a good portion of the time the discharge will occur at a deeper depth (to 14 m when the FPSO is fully loaded), where vertical mixing will play a larger role.

Effects

Any discharges of treated oily water from produced water at White Rose are likely to have *negligible* effects on marine mammals, since they are relatively unaffected by small amounts of oil (Section 5.9.1.3). Similarly, cumulative effects from discharges of produced water at Hibernia and Terra Nova are likely to be *negligible* and not significant.

4.5.2.6 Other Operational Discharges

As discussed in Section 4.5.1.4, the chronic subsurface releases of treated oily water (like those associated with deck drainage and bilge water) are likely to have *negligible* effects on marine mammals. Organic matter from sanitary and other domestic wastes will be quickly dispersed and degraded by bacteria. Effects of this small amount of organic matter and nutrients to receiving waters will be *negligible* for marine mammals.

As discussed in Section 4.5.1.4, the cumulative effects of discharges from offshore oil structures and vessels in the study area will be *not significant*.

4.5.2.7 Effects of Ships and Boats

All discharges from vessels, including sanitary and domestic waste, will be treated as described above. Overall, effects of vessel discharges on marine mammals would be *negligible*. Potential effects related to underwater noise are discussed in the following sections.

4.5.2.8 Effects of Helicopters

Effects of helicopters on the marine environment are mainly related to noise. This is discussed in Section 4.5.2.8.

4.5.2.9 Effects of Noise

The potential effects of underwater noise on marine mammals were discussed in Section 4.5.1.7. In that section, noise effects from stationary drilling rigs, from supply vessels, and from aircraft were considered. The principal underwater noise sources during production will be similar to those during project development, especially for ships and aircraft. Thus, the reader should refer to Section 4.5.1.7 in conjunction with the present section.

The development plan for White Rose calls for an FPSO. Most of the production machinery will be above the waterline, but propulsion engines and some other machinery will be below. Machinery will include diesel and gas generators, thrusters for propulsion, pumps, compressors, a crude oil separator and processing system, and life-support systems. Noise levels on an FPSO are similar to a semi-submersible drilling rig.

Most studies on the effects of noise associated with production activities have addressed sounds emitted by bottom-founded production platforms or artificial islands. Production platforms supported by metal legs have all of the machinery above the waterline and transmit very little sound to the water. Production platforms and artificial islands are relatively quiet. Noise levels and characteristics of a ship-shaped mono-hull FPSO are most likely to be similar to a large drillship. Drillships tend to be relatively noisy, partly because the ship's hull provides good coupling of sound into the water column.

At White Rose, the FPSO will be in the same area for 12 to 14 years. The effects on marine mammals will be minimized because it is a stationary source and habituation is likely. Overall, the effects of the stationary FPSO are likely to be of *low* magnitude in approximately a *10* km^2 area. The effects will last for the entire duration of the operation phase *(>72 months)*.

In addition to the noise from the FPSO, there will be additional sources of disturbance at this location. These include helicopters landing and taking off, supply vessels approaching and departing, the regular presence of a large shuttle tanker, and perhaps the presence of an active semi-submersible drilling rig. Taken together, the cumulative effects of these activities on marine mammals would be of 'low magnitude', affecting an area of *11 to 100* km^2 for the life of the operation phase. These disturbances would involve displacement rather than mortality and are reversible. Overall, the effects on marine mammals are *not significant*.

Marine mammals are adapted to living in the ocean, which is a naturally noisy environment that can experience elevated noise levels for extended periods during storms and strong wind events. The cumulative increased levels of low frequency ambient noise associated with oil and gas development on the Grand Banks will not be appreciable and in many cases, will be masked by natural events. It is concluded that the increased levels of ambient noise will not be sufficient to mask the natural communications used by marine mammals. In the absence of masking, it is possible that whales and seals will be disturbed by the anthropogenic noise sources from industry. However, there is no evidence of disturbance effects from distant ambient noise (Richardson et al. 1995). Based on studies in other areas, marine mammals would have to be close (within a few kilometres) to the actual sources of noise from oil and gas activities to be affected by them. Thus, the disturbance effects on marine mammals would be additive from a few isolated sources of noise rather than synergistic over a large area and will be *not significant* on a project basis or cumulatively.

4.5.2.10 Shore-based Facilities

No new facilities are required for the White Rose project. Existing infrastructure will be used.

As discussed in Section 4.6.1.8, combined activities from offshore oil development harbour facilities will not exceed those commonly associated with normal harbour operations nor will cumulative effects for marine mammals increase those predicted for White Rose.

4.5.3 Decommissioning

As previously mentioned, the White Rose site will be abandoned and restored to minimize permanent effects on the environment when the field has been depleted to a level where further production is uneconomic. The technology associated with abandonment and removal procedures is expected to change over the next 20 years, resulting in refined and new techniques.

Interactions between decommissioning activities and marine mammals are shown in section C of Table 4.4-1.

4.5.3.1 White Rose Development Area

Increased vessel activity during periods when facilities (decommissioning) are being removed may cause some disturbance to marine mammals. This disturbance will occur within relatively short periods of time and as discussed in Sections 4.5.1 and 4.5.2, and will have *negligible* effects on marine mammals. Abandonment of the White Rose site will probably have weak positive effects on marine mammals as potential disturbance related to offshore operations will be eliminated.

Similarly, the combined effects of abandonment at Terra Nova, Hibernia and exploration wells will *not significantly* effect marine mammals.

4.5.3.2 Shore-based Facilities

The shore-based facilities will be located in an existing port. As a result, cessation of White Rose activities is expected to have *negligible* effects on marine mammals.

Similarly, the cessation of Terra Nova and Hibernia activities will *not significantly* effect marine mammals.

4.5.4 Cumulative Effects Summary – Marine Mammals

Distant shipping noise dominates the ambient noise spectrum at frequencies of 20 to 300 Hz in the world's oceans. In coastal regions, the combined noise of many distant fishing vessels can contribute significantly to ambient noise (Richardson et al. 1995). There are approximately 3,000 to 3,300 transits of the Newfoundland waters annually by tankers, cargo ships, bulk carriers and container ships (W. Halley, pers. comm.). These ships are in transit to or from ports in Newfoundland, the St Lawrence Seaway and ports in the Maritime Provinces. This total does not include ships that did not visit Canadian ports. In addition, there were about 20,000 transits by fishing boats to and from NAFO area 3L (most of the Grand Banks) annually. In addition, there is the time spent by these vessels actually fishing on the Grand Banks. Thus, it is clear that shipping noise dominates low-frequency ambient noise on the Grand Banks.

Seismic exploration is the first stage in the search for potential hydrocarbon deposits. The amount of future seismic exploration on the Grand Banks will be highly variable and difficult to predict (J. McIntyre, pers. comm.). About four seismic operations per year may be planned for the entire Newfoundland offshore areas during the next few years.

Once a good geological prospect has been identified, an exploration well is drilled to determine whether hydrocarbons are present and to provide information on the characteristics of the reservoir. If hydrocarbons are present, delineation wells are drilled to determine the extent of the reservoir. Anywhere from two to nine exploration and delineation wells may be drilled per year in the Newfoundland offshore (*www.cnopb.nfnet.com*). Thus, one or two to four drilling platforms may be active in exploration type drilling at any one time. Supply boats support these operations.

A. Harvey and Company estimate that there will be an average of 25 supply vessel trips per month as a result of all oil operations on the Grand Banks (SEIS, Part Two). Tankers will make approximately 52 trips per year to the White Rose site and about 52 per year to the Terra Nova development.

At any one time on the Grand Banks, the oil and gas industry may be using or supporting one GBS, two FPSOs, 300 trips by supply vessels, 156 trips by oil tankers, two to four drill rigs used for exploration drilling, and four seismic operations per year. During the development phase of the projects, drill rigs will also be drilling production wells at Terra Nova and White Rose. At Hibernia, drilling will be done from the GBS. It is quite possible that production drilling will be going on at least two sites at the same time.

The trend in commercial shipping has been to larger and faster vessels. The principal sources of sound from a vessel are cavitation noise made by the propellers which generally increases with increasing speed of the vessel. Also, machinery noise from the engines increases at higher speeds (Urick 1983). In general, large ships are noisier than small ships (Urick 1983). However, cavitation is a function of the speed of the propeller blades and can be very high, and hence noisy, for even small vessels that are dealing with high loads, such as a fishing boat pulling a large trawl.

Because they are moving slowly and only to maintain position, FPSOs will be quieter than ships. Semi-submersible drill rigs of the type used on the Grand Banks are relatively quiet (Richardson et al. 1995). A supply ship will produce continuous broadband source levels of about 170 to 180 dB re 1 µ Pa–m (Richardson et al. 1995). Seismic arrays emit very short pulses at about 10-second intervals that have source levels in the range of 250 dB re 1 µ Pa–m (Richardson et al. 1995). Seismic arrays are configured such that most of the energy is directed downward. Even so, marine animals at considerable distance can hear them (see Davis et al. 1998 for a review).

Given the amount of commercial shipping and fishing activity that is present on the Grand Banks, it is safe to conclude that the underwater environment is already noisy. The incremental noise emanating from the White Rose project will have little effect on overall noise levels. However, the incremental sound made by the oil and gas industry (FPSOs, supply boats, individual drilling rigs, and seismic exploration) will add to the underwater ambient noise levels on the Grand Banks. The likelihood that the increased levels of ambient noise will affect marine mammals is discussed in the following paragraph.

The cumulative effects of activities within each of the development, production and decommissioning phases of White Rose are *not* expected to *significantly effect* marine mammals. The cumulative effects of the entire White Rose project (all three phases combined) are also *not* expected to cause *significant* effect. The effects of most specific activities (discussed in each section) are predicted to be *negligible* and no activities are expected to cause a significant effect on whales and seals.

Mitigation measures and standard treatment of fluids and solids produced during all project phases and other existing projects will prevent significant effect on marine mammal populations within the study area during the entire project.

4.5.5 Monitoring and Follow-up

Most of the monitoring and follow-up measures pertaining to various project activities during each phase of the project were discussed in Sections 4.3.1 to 4.3.3. Oil spill effects on marine mammals are discussed in Section 5.9.2.3.

4.6 SEA TURTLE VEC

Sea turtles are rare on the Grand Banks and particularly rare in the cold water of the White Rose area. Although there are no reliable data on sea turtle abundance and distribution on the Grand Banks, at-sea observer data collected by the U.S. National Marine Fisheries Service (NMFS) for the pelagic longline fishery provide some insight.

The major threats to sea turtle survival include disturbance and destruction of sensitive reproductive habitat on subtropical and tropical sandy beaches, ingestion of floating plastic debris, and commercial fisheries. In the Grand Banks area, sea turtles are caught incidental to the pleagic longline fishery directed at tunas, swordfish and sharks (NOAA 2000). During the period 1995 to 1998, the U.S. pelagic longline fleet caught at least 201 sea turtles in the Northwest Atlantic in the vicinity of the Grand Banks, the vast majority of which were released alive (Appendix Table A2 in NOAA 2000). The at-sea observer data indicate that the sea turtles are highly associated with very warm (>20°C) water (NOAA 2000). On the Grand Banks, turtles are most likely to be associated with eddies spun off from the Gulf Stream. There are no known persistent eddies in the White Rose area (J. Bobbitt, pers. comm.).

In most situations, effects of development, production, and decommissioning activities on sea turtles were assumed to be the same as those predicted for marine mammals (Tables 4.5-1 to 4.5-4). Like marine mammals, sea turtles can hear noise associated with ships and offshore oil structures, as the frequencies of their hearing sensitivity overlap with offshore industry noise (Ridgway et al. 1969). Effects assessments for accidental oil spills or blowouts and exposure to discharges containing oil were analyzed separately. A list of potential interactions of sea turtles with White Rose offshore oil activities are provided in Table 4.4-1; these are the same as for marine mammals.

The project will have a not significant negligible adverse effect on sea turtles during development, operations and decommissioning.

4.7 RESIDUAL EFFECTS SUMMARY

The predicted residual environmental effects of project development, production and possible accidental events on fish and fish habitat are assessed as adverse, but not significant. The residual environmental effects of project decommissioning on fish and fish habitat are predicted to be primarily positive. The overall effect of the project on fish and fish habitat is assessed as not significant (Table 4.7-1).

The residual environmental effects of project development and production on marine birds are assessed to be adverse, but not significant, while any effects during decommissioning will be primarily positive. The residual environmental effect of an accidental event such as a significant oil spill on marine birds, although unlikely, is assessed to be adverse and significant. The overall effect of the project on marine birds is assessed as not significant (Table 4.7-1).

The residual effects of project development and production and in the case of an accidental event on marine mammals and sea turtles are assessed to be adverse, but not significant. Any predicted effects to this VEC as a result of project decommissioning are predicted to be primarily positive. The overall environmental effect of the project on marine mammals and sea turtles is assessed to be not significant (Table 4.7-1).

In summary, after mitigation measures have been implemented, the overall predicted effects of the project on the biophysical environment are assessed as not significant. The only exception is the potential effect of a significant offshore oil spill on marine birds. However, the potential for such an event is, as discussed previously, very low. The capacity of renewable resources to meet present and future needs is not likely to be significantly affected by the proposed project.

Table 4.7-1 Residual Environmental Effects Summary Matrix – Biophysical VECs

Phase	Residual Environmental Effects Rating, including Cumulative Effects	Level of Confidence	Likelihood	
			Probability of Occurrence	Scientific Certainty
Fish and Fish Habitat				
Development	NS	3	3	3
Production	NS	3	3	3
Decommissioning	P	3	3	3
Accidental Events[a]	NS	3	1	3
Project Overall	NS	3	3	3
Marine Birds				
Development	NS	3	3	3
Production	NS	3	3	3
Decommissioning	P	3	3	3
Accidental Events[a]	S	3	1	3
Project Overall	NS	3	3	3
Marine Mammals and Sea-Turtles				
Development	NS	3	3	3
Production	NS	3	3	3
Decommissioning	P	3	3	3
Accidental Events[a]	NS	2	1	2
Project Overall	NS	3	3	3

Key:

Residual Environmental Effects Rating:

S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:

1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[a] From Section 5.9

5 OIL SPILLS

5.1 INTRODUCTION

Two types of environmentally-threatening accidents that could occur during the White Rose oilfield development project are oil-well blowouts and "batch" spills. Blowouts are continuous spills lasting hours, days or weeks that could involve the discharge of large volumes of petroleum gas into the atmosphere and large amounts of crude oil into surrounding waters. Blowouts could occur from accidents during development drilling, well-completion activities, workovers, and various production activities including wirelining, coiled tubing and snubbing operations.

Batch spills are instantaneous or short-duration discharges of oil that could occur, for example, from accidents on the FPSO where oil is stored and handled, or accidents associated with the loading of oil onto the shuttle tankers that will move oil from the FPSO to ports.

The purpose of this section is to discuss the likelihood, control and effects of such spills. Section 5.9 provides effects predictions for accidental events, and Chapter 6 deals in detail with Mitigation Measures and Contingency Planning.

5.1.1 General Oil Pollution Record of the Offshore Oil and Gas Industry

Regulatory requirements relating to oil spill prevention in the Canadian offshore are among the most stringent in the world. Compared to other industries that have potential for discharging petroleum oil into the marine environment, the industry of exploring, developing and producing offshore oil and gas has a relatively good record. As noted in a study on oil pollution by the U.S. National Academy of Sciences (see Table 5.1-1), this industry contributes only 1.5 percent of the total petroleum input to the world's oceans.

The record is particularly good in the U.S. Outer Continental Shelf (OCS), where over 24,000 wells were drilled and nine billion (10^9) barrels of oil and condensate were produced from 1971 to 1995; yet only eight blowouts occurred that involved any discharge of oil or condensate. The total oil discharged in the eight events was only 999 barrels. The oil spill prevention mechanisms built into offshore oil and gas activities in North America are obviously effective.

Because this study derives spill and blowout statistics for White Rose from worldwide statistics, it is assumed that the practices and technologies that will be used at White Rose will be at least as safe as those used in other offshore oil and gas operations around the world and in accordance with the accepted practices of the international petroleum industry. Because statistics on U.S. offshore oil and gas operations are used extensively in this analysis, it is specifically assumed that White Rose operations are comparable from a safety viewpoint to operations in U.S. OCS waters.

Table 5.1-1 Input of Petroleum Hydrocarbons into the Marine Environment

Source	Best Estimate (million tonnes per annum)	Percent
Natural Sources		
Marine seeps	0.2	6.2 percent
Sediment erosion	0.05	1.5 percent
(Total natural sources)	**(0.25)**	**(7.7 percent)**
Offshore Production	**0.05**	**1.5 percent**
Transportation		
Tanker operations	0.7	21.5 percent
Dry-docking	0.03	0.9 percent
Marine terminals	0.02	0.6 percent
Bilge and fuel oils	0.3	9.2 percent
Tanker accidents	0.4	12.3 percent
Nontanker accidents	0.02	0.6 percent
(Total transportation)	**(1.47)**	**(45.2 percent)**
Atmosphere	**0.3**	**9.2 percent**
Municipal and Industrial Wastes and Runoff		
Municipal wastes	0.7	21.5 percent
Refineries	0.1	3.1 percent
Nonrefining		
Industrial wastes	0.2	6.2 percent
Urban runoff	0.12	3.7 percent
River runoff	0.04	1.2 percent
Ocean dumping	0.02	0.6 percent
(Total wastes and runoff)	**(1.18)**	**(36.3 percent)**
TOTAL	**3.25**	**100.0 percent**
Source: NAS 1985		

Most spill statistics used in this report are taken from publications of the U.S. Minerals Management Service (MMS), which works exclusively with the oil volume units of barrels: there are 6.29 barrels in a cubic metre (m^3).

5.1.2 Sources of Information

Statisticians at the U.S. MMS have produced a large body of literature on marine oil-spill probability in the U.S. OCS. Because these oil-spill statistics have been extensively peer-reviewed and are updated regularly, they will be used as the primary source for this review.

Other key sources of information are referenced, all focusing on blowouts and spills from offshore oil and gas activities. The first is a 1981 study by Gulf Research and Development Company entitled “Analysis of Accidents in Offshore Operations where Hydrocarbons were Lost” (Gulf Canada 1981). This study, performed in support of oil development activities in the Canadian Southern Beaufort Sea, is old but remains particularly good in analyzing the causes of accidents and spills, mostly in terms of the U.S. Gulf of Mexico oil and gas industry, but also in terms of the Alaska and North Sea experiences.

The next two studies focus exclusively on the problem of blowouts. One study conducted in 1985 by Manadrill Drilling Management Inc. concentrates on the issue of relief well drilling capability in Canadian offshore waters, especially in the southern Beaufort Sea, but as well, provides a good summary of previous studies on offshore blowouts. The other blowout study is one that was prepared by Adams Pearson Associates Inc. (1991) for the former Canadian Petroleum Association on the subject of "worst case" blowouts, mostly in reference to operations in the Canadian Beaufort Sea. This study does a good job in explaining in relatively simple terms how blowouts happen and how they tend to stop naturally.

The most recent references are three comprehensive reports prepared in Europe. The first is called the World Offshore Accident Databank (WOAD) Statistical Report prepared in 1994 by DNV Technica Norge. This provides detailed statistics on accidents to offshore units engaged in oil and gas activities in the period from 1970 to 1993. The other two European studies were prepared for the Oil Industry International Exploration & Production Forum (E&P Forum). The first, completed in 1992, again by DNV Technica, is entitled "Hydrocarbon Leak and Ignition Data Base" (E&P Forum 1992). This study is based on oil company reports of spills and blowouts that have occurred during offshore exploration and production activities. Most (85 to 90 percent) of the blowout and spill statistics are derived from activities in the U.S. Gulf of Mexico Outer Continental Shelf (USGOM-OCS), but data from the North Sea are also included; the period covered is 1970 to 1989. The most recent study for the E&P Forum, completed in October 1996 by a subcommittee of E&P Forum members, is entitled "Quantitative Risk Assessment (QRA) Data Sheet Directory".

The last three studies are very detailed, but the problem is that there are statistical discrepancies between them. The most recent of the three studies, the QRA Directory (E&P Forum 1996), indicates that it has resolved discrepancies identified between the earlier studies, but inconsistencies still remain. Generally, the blowout frequencies stated in the QRA Directory seem to be somewhat lower than those reported in recent U.S. government publications. For example, in MMS (1994), 25 blowouts during workovers are reported to have happened in the USGOM-OCS from 1970 to 1989, but in the E&P Forum studies, only 16 such blowouts are reported for both the USGOM-OCS and the North Sea. The difference might be due to the possibility that DNV Technica and/or E&P Forum have culled the official blowout database to remove "blowouts" that did not involve a discharge of hydrocarbons into the environment, that were caused by "external loads" like acts of war or hurricanes, or that were "unfairly" reported one way or the other. In any case, for the purposes of this study, where discrepancies are found, the more conservative statistics (such as, larger number blowouts) from MMS are used in calculating blowout frequencies.

5.1.3 White Rose and Worldwide Statistics of Importance to this Analysis

This analysis makes reference to many statistics, so it is convenient at the start to summarize data related to the project itself and data related to drilling, production and spills from similar projects in other parts of the world.

The relevant statistics (initial estimates) related to the White Rose project are summarized in Table 5.1-2. Important statistics from other offshore oil and gas producing areas of the world are provided in Table 5.1-3.

Table 5.1-2 White Rose Statistics of Importance to Study

	Range	**Average***
Years of Production	12 to 14	13
Oil Producer Well-Years	140	140
Total Oil Production (million barrels)	250	250
Well Numbers		
• Development Oil Producers	10 to 14	11
• Development Gas Injectors	2 to 3	2
• Development Water Injectors	6 to 8	7
Total Wells Drilled	18 to 25	20
Years to Drill Wells	2 to 4	3
* Initial estimates used in the calculations		

Table 5.1-3 Important Statistics: Worldwide, Gulf of Mexico, Offshore Norway North Sea and U.K. North Sea

Worldwide Offshore	Statistic	Source
Exploration wells drilled worldwide, 1955-1980	11,737	Gulf 1981
Development wells drilled worldwide, 1955-1980	24,896	Gulf 1981
Approx. exploration wells drilled worldwide to 1988	20,000	Sharples et al. 1989
Approx. develop./production wells drilled worldwide to 1988	51,000	Sharples et al. 1989
Approx. cumulative offshore oil produced to January 1980 (excluding Lake Maricaibo)	$35.2x10^9$ bbl	Gulf 1981
Blowouts during exploration drilling (incl. S.G.), 1955-1980	96	Gulf 1981
Blowouts during development drilling (incl. S.G.), 1955-1980	66	Gulf 1981
Other blowouts (during production, workovers, etc.),1955-1980	52	Gulf 1981
Total shallow-gas blowouts, 1955-1980	54	Gulf 1981
Blowouts during exploration drilling (incl. S.G.), 1980-1996	81	E&P Forum 1996
Blowouts during development drilling (incl. S.G.), 1980-1996	51	E&P Forum 1996
Other blowouts (during production, workovers, etc.),1980-1996	73	E&P Forum 1996
United States, Gulf of Mexico (USGOM) and Outer Continental Shelf (USOCS)		
Exploratory wells drilled in USGOM, 1955-1980	4,794	Gulf 1981
Development wells drilled in USGOM,1955-1980	12,390	Gulf 1981
Total wells drilled in USGOM, 1955-1980	17,184	Gulf 1981
Total wells drilled in USOCS (96 percent in GOM), 1971-1995	24,237	MMS 1997
Total wells drilled in USOCS, 1955-1995	33,288	MMS 1994
Approx. cumulative total oil produced in OCS to Jan.1980	$8.8x10^9$ bbl	Gulf 1980
Cumulative total oil produced in OCS, 1971 to end 1995	$8.53x10^9$ bbl	MMS 1997
Total blowouts of all kinds, 1955-1980	98	Gulf 1981
Blowouts during exploration drilling (incl. S.G.),GOM,1955-80	30	Gulf 1981
Blowouts during development drill. (incl. S.G.),GOM,1955-80	36	Gulf 1981
Production and workover blowouts, GOM, 1955-1980	32	Gulf 1980
Total shallow gas blowouts, U.S.GOM, 1955-1980	29	Gulf 1981
Exploratory drilling blowouts, USOCS, 1971-1995	49	MMS 1997
Development drilling blowouts, USOCS, 1971-1995	45	MMS 1997
Production, workover & completion blowouts, OCS, 1971-95	57	MMS 1997
Important Statistics: Worldwide, Gulf of Mexico, Offshore Norway, and U.K. North Sea		
Norwegian Offshore		
Exploration and appraisal wells drilled, 1966-1998	939	NPD 1998
Development wells drilled, 1966-1998	1,501	NPD 1998
U.K. North Sea		
Exploration wells drilled, 1964-1980	838	Gulf 1981
Development wells drilled, 1964-1980	721	Gulf 1981
Blowouts during all stages, 1964-1980	6	Gulf 1981
Exploration and appraisal wells drilled, 1988-1997	1,694	Meltzer 1998
Development wells drilled, 1988-1997	3,932	Meltzer 1998
North Sea U.K. & Norwegian Combined		
Exploration wells drilled, 1980-1992	2,315	E&P Forum 1996
Development wells drilled, 1980-1992	2,389	E&P Forum 1996
Exploration drilling blowouts, 1980-1992	16	E&P Forum 1996
Development drilling blowouts, 1980-1992	4	E&P Forum 1996
S.G. = Shallow Gas Blowouts		

5.1.4 Categories of Spill Size

For convenience, five spill size categories have been selected and analysed. The first category is for "extremely large" spills, arbitrarily defined as spills larger than 150,000 bbl (23,800 m^3). Good worldwide statistics are available for this size range. The seconds and third categories are for “very large” and “large” spills, defined by the U.S. MMS as spills larger than 10,000 barrels (1,590 m^3) and 1,000 barrels (159 m^3), respectively. The fourth category is for spills in the range of 50 to 999 bbl, and the fifth category is for spills in the 1 to 49 bbl category. In summary, the spill size classifications used in this study are:

Extremely Large spills:	>150,000 bbl	(>23,850 m^3 or >20,830 tonnes)
Very Large spills	>10,000 bbl	(>1,590 m^3 or >1,390 tonnes)
Large spills:	>1,000 bbl	(>159 m^3 or >139 tonnes)
Medium spills:	50 to 999 bbl	(7.95 m^3 to 158.9 m^3)
Small spills:	1 to 49.9 bbl	(0.08 m^3 to 7.94 m^3)

Note that the top three categories are cumulative, for example, the large-spill category (>1,000 bbl) includes the very large and extremely large spills, and the very large category includes extremely large spills, and so on.

5.1.5 Section Structure

The analysis begins with a review of the probabilities of offshore blowouts that involve the discharge of oil, and those that involve gas only. This is followed by a probability analysis related to other kinds of spills of oil that can happen on the platforms over the course of the project. Finally, an analysis is performed of spills that might occur in association with the operation of loading oil from the FPSO to the shuttle tankers.

Each of the following sections is difficult to read and digest because of the large number of statistics presented. To help in this regard, a summary table is presented at the end of the section that includes all the key statistics used and derived.

5.2 BLOWOUTS

In the oil and gas industry, a distinction is made between two stages of petroleum field drilling: exploration drilling (including "delineation" drilling), where knowledge of the geological and depositional environment is speculative or limited, and development drilling, where the structure and the drilling parameters are better defined. At this time, exploration drilling at the White Rose sites is completed, but an estimated 20 development wells require drilling. Therefore, the analysis concentrates on statistics related to development drilling, although reference is made to exploration-related statistics where appropriate. Blowouts can also happen during production, workovers and well completion activities, and these must be addressed as well.

5.2.1 Extremely Large and Very Large Oil Spills from Blowouts

5.2.1.1 Historical Statistics

The main environmental concern with the White Rose project is the possibility of a well blowout occurring and discharging tens or even hundreds of thousands of barrels of crude oil into the marine environment. In the U.S., only two moderate-size oil-well blowouts involving oil spills greater in size than 50,000 barrels have occurred since offshore drilling began in the mid-1950s. One must look beyond the U.S. to find a reasonable database on very large and extremely large oil-well blowouts. All worldwide blowouts involving the spillage of more than 10,000 barrels each are listed in Table 5.2-1. For the definition of "extremely large" spills, that is, oil spills 150,000 barrels in size or greater, it is seen that there have been five such spills in the history of offshore drilling, two of which occurred during development drilling and two of which occurred during production or workover activities. The fifth was from exploration drilling.

Blowouts During Drilling

Spill frequencies are best expressed in terms of a risk exposure factor such as number of wells drilled. On a worldwide basis, it has been estimated that 36,633 offshore wells were drilled from 1955 to 1980, of which 24,896 were development wells (Gulf 1981). The total number of development wells drilled up to 1988 has been estimated to be 51,000 (Sharples et al. 1989). There have been two extremely large spills (>150,000 bbl) during offshore development drilling (Table 5.2-1), so the frequency up to 1988 has been 3.9×10^{-5} spills per well drilled (2/51,000) or one such spill for every 25,500 wells drilled. A similar analysis can be done for so-called "very large" spills, that is those larger than 10,000 barrels. Up to 1988, four development drilling blowouts have produced spills in this category (Table 5.2-1), so the spill frequency for these become 7.8×10^{-5} spills per well drilled (4/51,000). This is one spill for every 12,750 wells drilled, or 0.007 percent of wells drilled will have a spill of this size.

Table 5.2-1 Historical Large Oil Spills from Offshore Oil-Well Blowouts

Area	Reported Spill Size (bbl)	Date	Operation Underway
Mexico (Ixtoc 1)	3,000,000	1979	Exploratory Drilling
Dubai	2,000,000	1973	Development Drilling
Iran*	?	1983	Production
Mexico	247,000	1986	Workover
Nigeria	200,000	1980	Development Drilling
North Sea/Norway	158,000	1977	Workover
Iran	100,000	1980	Development Drilling
U.S.A., Santa Barbara	77,000	1969	Production
Saudi Arabia	60,000	1980	Exploratory Drilling
Mexico	56,000	1987	Exploratory Drilling
U.S.A., S. Timbalier 26	53,000	1970	?
U.S.A., Main Pass 41	30,000	1970	Production
U.S.A., Timbalier Bay/Greenhill	11,500	1992	Production
Trinidad	10,000	1973	Development Drilling

Source: Gulf 1981, updated by reference to the Oil Spill Intelligence Report
* The Iranian Norwuz oil-well blowouts in the Gulf of Arabia, which started in February 1983, were not caused by exploration or drilling accidents but were a result of military actions during the Iraq/Iran war.

The number of wells drilled worldwide since 1988 is not readily available, but the literature indicates that only one large oil well blowout larger than 10,000 barrels occurred since that time (this was the Timbalier Bay production-well blowout occurring in state waters of the U.S. Gulf of Mexico in September, 1992). This means that estimates based on more current statistics would be even lower than those noted above because no drilling-related blowouts have occurred since 1988. This strongly suggests that improvements in technology and procedures now in place have been effective in reducing blowout frequency.

Blowouts During Production and Workovers

The occurrence of two extremely large (>150,000 bbl) and five very large (>10,000 bbl) oil spills from blowouts during production and workovers are indicated in Table 5.2-1. Developing an exact risk exposure for these events is not easy because of lack of data, but it is estimated that the total oil produced offshore on a worldwide basis up to the end of 1995 has been approximately 100 billion barrels, and that the total producing oil well-years has been 200,000 well-years (based on information in Gulf (1981), NAS (1985), E&P Forum (1992), and MMS (1997)). Generally, in analyzing accidents in the oil and gas industry, the exposure variable of "well-years" is used to normalize data for the continuous operation of production. This exposure is also convenient to use for workovers inasmuch as these maintenance activities, although not being continuous operations, usually occur with regularity, say, about every five to seven years during the lifetime of a well.

On this basis, the worldwide frequency of extremely large oil spills (>150,000 bbl) from oil-well blowouts that occurred during production or workovers is 2/200,000 = 1.0 x 10^{-5} blowouts/well-year. For very large spills (>10,000 bbl) the number is 2.5 x 10^{-5} blowouts/well-year.

Finally, it is emphasized that the spill frequencies derived above for extremely large spills, however low, are based on spills in countries (except Norway) that do not generally have regulatory standards as stringent as those existing in North America. For example, the largest oil spill in history, the Ixtoc I oil-well blowout in the Bay of Campeche, Mexico, that occurred in 1979, was caused by drilling procedures (used by PEMEX, Mexico's national oil company) that are not practiced in U.S. or Canadian waters and which are contrary to U.S. and Canadian regulations and to the accepted practices within the international oil and gas industry.

5.2.1.2 Calculated Frequencies for the White Rose Project

The various statistics associated with the White Rose project are noted in Table 5.1-2. As seen, there will be a total of 20 development wells drilled (over three years) and 140 producer-well-years of operation. Using the above worldwide spill frequency statistics as a basis for prediction, the spill frequencies (in this and other similar calculations in the report, spill frequency rates are kept as three-decimal data, and the probability numbers are rounded off to two decimal points) estimated for the projects would be:

- Predicted frequency of extremely large oil spills (>150,000 bbl) from blowouts during a drilling operation, based on an exposure of wells drilled: 20 x 3.9 x 10^{-5} = 7.80 x 10^{-4}. This represents a 0.08 percent chance over the three-year drilling period, or an average annual probability of one-in-3,800.

- Predicted frequency of very large oil spills (>10,000 bbl) from drilling blowouts based on an exposure of wells drilled: 20 x 7.8 x 10^{-5} = 1.56 x 10^{-3}, or a 0.16 percent chance over the drilling period. On average, the annual probability is one-in-1,900.

- Predicted frequency of extremely large oil spills (>150,000 bbl) from production/workover blowouts, based on an exposure of well-years: 140 x 1.0 x 10^{-5} = 1.40 x 10^{-3} or a 0.14 percent change over the project's lifetime (13 years), or a one-in-9,300 chance per year. This means that if the project continued forever at the same, fixed conditions, one could expect an oil spill larger than 150,000 barrels once every 9,300 years.

- Predicted frequency of very large oil spills (>10,000 bbl) from production/workover blowouts, based on an exposure of well-years: 140 x 2.5 x 10^{-5} = 3.50 x 10^{-3} or a 0.35 percent chance over the project's lifetime (13 years), or a one-in-3,700 chance per year.

5.2.2 Blowouts Involving Gas Only or Small Discharges of Oil

Gas blowouts from offshore wells that do not involve a discharge of liquid petroleum are generally believed to be innocuous to the marine environment. Such blowouts do, however, represent a threat to human life and property because of the possibility of explosion and fire.

5.2.2.1 Historical Statistics

Historical statistics for blowouts involving only gas or small oil discharges are best taken from U.S. sources because the U.S. MMS keeps track of spills down to one barrel in size. This is not the case in other parts of the world. The necessary information for the exercise is provided in Table 5.2-2. The data represent the 25-yr period from 1971 to 1995. Note that there are no large spills (>1,000 bbl) in the entire database. If the table had started in 1970, however, two very large blowout spills would have been shown involving 30,000 barrels and 53,000 barrels respectively (see Table 5.2-1). Because a full set of spill data is not readily available for 1970, Table 5.2-2 will be used as is, but it should be kept in mind that spills from blowouts larger than those shown in the table are definitely possible, as was the case in 1970.

Development Drilling

The total number of development wells drilled in the U.S. Federal OCS is not shown in Table 5.2-2, but it is easily derived from other sections of U.S. MMS (1997) and from E&P Forum (1996); the number is approximately 16,000. The number of blowouts from development drilling is shown to be 39 (the six blowouts from sulphur drilling are removed) therefore, the blowout frequency is 39/16,000 or 2.4×10^{-3} blowouts per well drilled. No oil was spilled in any of these blowouts. The information suggests that most blowouts occurred in gas-prone fields or were shallow-gas blowouts, and further suggests that blowouts from deep, development drilling in oil-prone fields are improbable events. As a worst-case, however, it will be assumed that the above blowout frequency applies to the current study.

Table 5.2-2 Blowouts and Spillage from U.S. Federal Offshore Wells Compared to Crude Oil and Condensate Production on Federal OCS Leases, 1971-95

Year	Well Starts	Drilling Blowouts				Non-drilling Blowouts								
		Exploration		Development		Production		Workover		Completion		Total Blowouts		OCS Production
		No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	MMbbl
1971	851	1	0	1	0	2	450	1	0	0	0	5	450	406.9
1972	845	2	0	2	0	1	0	0	0	0	0	5	0	396.0
1973	820	2	0	1	0	0	0	0	0	0	0	3	0	384.8
1974	802	1	0	1	0	4	275	0	0	0	0	6	275	354.9
1975	842	4	0	1	0	0	0	1	0	1	0	7	0	325.3
1976	1,078	1	0	4	0	1	0	0	0	0	0	6	0	314.5
1977	1,240	3	0	1	0	1	0	3	0	1	0	9	0	296.0
1978	1,164	3	0	4	0	0	0	3	0	1	0	11	0	288.0
1979	1,140	4	0	1	0	0	0	0	0	0	0	5	0	274.2
1980	1,158	3	0	1	0	2	1	1	0	1	0	8	1	274.7
1981	1,208	1	0	2	0	1	0	3	64	3	0	10	64	282.9
1982	1,255	1	0	4	0	0	0	4	0	0	0	9	0	314.5
1983	1,180	5	0	5	0	0	0	2	0	0	0	12	0	350.8
1984	1,352	3	0	1	0	0	0	1	0	0	0	5	0	385.1
1985	1,169	3	0	1	0	0	0	2	40	0	0	6	40	380.0
1986	694	0	0	1	0	0	0	1	0	0	0	2	0	384.3
1987	845	2	0	0	0	3	0	1	0	2	60	8	60	358.8
1988	950	1	0	1	0	0	0	1	0	0	0	3	0	332.7
1989	947	2	0	[1]5	0	[2]3	0	1	0	0	0	11	0	313.7
1990	1,018	1	0	1	0	0	0	3	9	1	0	6	9	304.5
1991	726	3	0	[3]3	0	0	0	0	0	0	0	6	0	326.4
1992	431	2	100	0	0	0	0	0	0	0	0	2	100	337.9
1993	879	0	0	[4]4	0	0	0	0	0	0	0	4	0	352.7
1994	845	0	0	0	0	0	0	1	0	0	0	1	0	370.4
1995	798	1	0	0	0	0	0	0	0	0	0	1	0	429.2
Total	**24,237**	**49**	**100**	**[5]45**	**0**	**[5]18**	**726**	**29**	**113**	**10**	**60**	**151**	**999**	**8,539.2**

(Source: U.S. MMS 1997)
[1] Two of the drilling blowouts occurred during drilling for sulphur.
[2] One blowout occurred during abandonment operations.
[3] Two of the drilling blowouts occurred during drilling for sulphur.
[4] Two of the drilling blowouts occurred during drilling for sulphur on the same well.
[5] The corresponding numbers in the original source (MMS 1997) were typographical errors.

Only crude oil and condensate blowout spillage is given in Table 5.2-2 (in barrels) for the 151 blowouts that occurred during the past 25 years.

The above-noted blowout frequency of 39 blowouts per 16,000 offshore wells, or one blowout per 410 development wells drilled, has remained consistent over the years, and the same frequency seems to apply around the world regardless of offshore drilling environment (Gulf 1981; E&P Forum 1992; Manadrill 1985; CPA 1989).

Blowouts During Production, Workovers and Completions

The best accident exposure variable to use for the operations of production and workovers is well-years. It is also convenient to link completions and re-completions to well-years of operation. The number of oil well-years for the population in Table 5.2-2 from 1971 through 1995 can be calculated from another table in U.S. MMS (1997) (page 19); the number is 107,717 producing oil well-years.

From Table 5.2-2 it is seen, for all the gas-producing areas and oil-producing areas of the U.S. Federal OCS, that 57 blowouts occurred during production, workovers and completions. Fifty involved gas only and seven involved oil. Therefore, the frequency of blowouts that produced an oil spill from oil-producing wells during a production operation or workover is calculated to be: 7/107,717 or 6.5×10^{-5} blowouts/well-year. Note that the average size of the seven spills was only 130 barrels.

5.2.2.2 Calculated Frequencies for the White Rose Project

There will be 20 development wells drilled during the White Rose project, so the calculated blowout frequency becomes $20 \times 2.4 \times 10^{-3} = 0.048$, or a 4.8 percent chance of a blowout over the three-year drilling period, or a one-in-63 (or 1.6 percent) chance per year. According to the statistics in Table 5.2-2, however, the chances of having an oil discharge associated with the blowout are extremely low, actually zero according to the table. It should be remembered, however, that large and even extremely large spills have occurred during development drilling, as shown in Table 5.2-1.

For blowouts that involve some oil and, that occur during production and workovers the statistic for White Rose becomes 140 well-years x 6.5×10^{-5} blowouts/well-year or 9.1×10^{-3} blowouts over the course of the entire (average) 13-yr project, or about a one-in-1,400 chance per year. Again, this means that if the projects were endless, one might expect a blowout involving some oil every 1,400 years.

5.3 PLATFORM SPILLS INVOLVING LARGE OIL SPILLS (>1000 BBL)

5.3.1 Historical Record

There have been very few large spills from platforms operating in U.S. OCS waters. In addition to the four from blowouts noted in Table 5.2-1, there have been six others (as noted in Table 5.3-1) which includes all U.S. platform spills up to the end of 1995. These all occurred prior to 1980. U.S. MMS statisticians responsible for analyzing and predicting oil spill frequencies associated with offshore oil and gas activities in the OCS have decreased the estimate gradually over the past decade mostly in recognition of a statistical trend towards lower spill frequency. The latest estimate derived from statistics in Anderson and LaBelle 1994 is 3.6 x 10^{-5} spills/well-year for spills equal or greater than 1000 barrels and 1.3 x 10^{-5} spills/well-year for spills equal or greater than 10,000 barrels. These numbers were derived from equivalent statistics in Anderson and LaBelle 1994 involving an exposure of "billions of barrels oil produced" for the period 1981 to 1993. During this period, 7.74 billion barrels were produced in 97,921 well-years (MMS 1994).

Table 5.3-1 Oil Spills of ³ 1,000 bbl from Platforms on the U.S. OCS, 1964 –1995

Date	Location	Size (bbl)	Cause
04/08/64	Eugene Island Block 208	2,559	Collision
10/03/64	Eugene Island Ship Shoal	11,869	Hurricane (7 platforms)
07/19/65	Ship Shoal Block 29	1,688	Blowout (condensate)
01/28/69	Santa Barbara Channel	77,000[a]	Blowout
03/16/69	Ship Shoal Block 72	2,500	Collision, weather
02/10/70	Main Pass Block 41	30,000	Blowout
12/01/70	South Timbalier Block 26	53,000	Blowout
01/09/73	West Delta Block 79	9,935	Storage tank rupture
11/23/79	Main Pass Block 151	1,500[b]	Collision, weather, tank spill
11/13/80	High Island Block 206	1,456	Pump failure, hurricane, tank spill
09/29/92	Timbalier Bay/Greenhill	11,500[c]	Production well blowout

Source: MMS 1997
a. Estimates vary between 10,000 to 77,000 bbl
b. Refined product
c. This spill was in Louisiana State waters and not OCS waters, but is included in table for interest.

Please note that the above statistic for spills greater than 10,000 bbl (that is, 1.3 x 10^{-5}) is smaller than the statistic derived earlier for blowouts > 10,000 bbl (that is, 2.5 x 10^{-5}). This is impossible because the first category includes blowout spills. The reason for the anomaly is that the U.S. record was used for the former and the worldwide record was used for the latter. The results simply mean that spills occur less frequently in U.S. waters compared to the rest of the world.

5.3.2 Calculated Frequencies for White Rose

The well-years for White Rose is 140, therefore, the estimated frequency of any platform spills larger than 1,000 bbl and 10,000 bbl, including blowout spills, is 140 x 3.6 x 10^{-5} = 5.04 x 10^{-3} spills larger than 1,000 bbl and 140 x 1.3 x 10^{-5} = 1.82 x 10^{-3} spills larger than 10,000 barrels, respectively. The equivalent annual probabilities are one in 2,600 and one in 7,100.

5.4 PLATFORM SPILLS INVOLVING SMALL DISCHARGES

5.4.1 Historical Record

Small spills occur with some regularity at offshore platforms. Spills of size larger than one barrel of all pollutants from facilities and operations on Federal OCS leases from the period 1971 to 1995 are indicated in Table 5.4-1, which is derived from a more detailed table in U.S. MMS (1997). The spills involved various pollutants including crude oil, condensate, refined product, mineral oil, and diesel. The period between 1971 and 1995 involved the production of 8.5 billion barrels of oil and condensate and 107,717 oil well-years of production activity (MMS 1997). This means that 1,857/107,717 = 1.7×10^{-2} spills having size between 1 and 49.9 barrels occurred for every well-year, and that 86/107,717 or 8.0×10^{-4} spills having size in the range of 50 to 999 barrels occurred for every well-year.

Table 5.4-1 Spill Frequency from Platforms for Spills in the Size Ranges of 1-49 bbl and 50-999 bbl

Spill Size Range	Number of Spills	Spills per Well-Year
1 - 49 bbl	1,857	1.7×10^{-2}
50-999 bbl	86	8.0×10^{-4}

Source: U.S. MMS 1997
Total volume of 1,857 + 86 spills = 123,023 barrels
(U.S. OCS 1971 – 1995)

The 1,857 spills noted in Table 5.4-1 (including all pollutants, not just crude oil) occurred mostly in the early years of the reporting period (1971 to 1995). For example, over 45 percent occurred in the five-year period of 1971 to 1975, and over 60 percent occurred in the 1970s. This suggests that the situation has improved significantly over the years, either because of better practices, more experience with routine operations, and perhaps better regulatory control.

5.4.2 Calculated Frequencies for White Rose

The predictions, based on historical data, are $140 \times 1.7 \times 10^{-2} = 2.38$ spills less than 50 barrels over the course of the average 13-yr project (one every five years), and $140 \times 8.0 \times 10^{-4} = 0.112$ spills in the size range of 50 to 999 barrels, or a 14 percent chance of having one such spill over the course of the project (one in 120 years).

5.5 SPILLS DURING TANKER LOADINGS

Spills are possible when White Rose crude oil is transferred from the FPSO to shuttle tankers. Developing predictions of frequencies for such spills is difficult at this time because the design of the loading/lifting system has not been finalized. As well, the technologies involved in offshore tanker loadings have changed considerably over the last few years, making questionable the use of historical spill statistics for predicting future spill frequencies; the literature seems to indicate a dramatic drop in spill frequencies over the last few years as better technologies have been adopted. The issue is discussed in three different ways below.

5.5.1 Experience in the U.K. Sector of the North Sea

The area that has the most experience with the use of tankers to lift offshore oil is the North Sea. The U.K. sector has been using tankers since 1976 to transport oil from the offshore production facilities to shore, using both Single Buoy Mooring (SBM) and Single Point Mooring (SPM) systems. There are two separate reports on this experience which provide somewhat different results, as described below.

5.5.1.1 Experience During 1976-1979 (as reported in Gulf (1981))

The breakdown of statistics from 1976 (when production began) to 1979 is available in Gulf (1981). Of all spills during E&P activities in the U.K. sector of the North Sea, 23 percent (that is 34 spills) involved offloading accidents and accounted for 73 percent of the total oil spilled. Ninety-four percent of these 34 spills were less than 100 barrels each, with an average spill size of 18 barrels.

There were two large spills (>1,000 barrels), each having a volume of 4,000 barrels. The volume of oil lifted during 1976 to 1979 inclusive was 870 million barrels, therefore, the frequency of large spills was 2/0.87 or 2.3 spills per billion barrels offloaded.

5.5.1.2 Experience During 1975-1993 (as reported by E&P Forum (1996))

It is noted in E&P Forum (1996) that pollution incidents associated with liftings should be grouped according to the lifting system. Spills associated with non-CALM (Catenary Anchor Leg Mooring) systems are provided in Table 5.5-1. The CALM system was a first generation system and has been phased out. Offshore loading statistics from the UK Department of Trade and Industry (DTI) pollution reports over the years 1977-93 (“Offshore Pollution Reports from Field Operators over 1977-93”) are provided in Table 5.5-1.

Table 5.5-1 Pollution Incidents - UK Offshore Loading 1975-93 (non-CALM systems)

Spill source	Total number	Total vol (bbls)	Min size (bbls)	Max size (bbls)	Ave. size (bbls)
Storage	36	4,343	0.1	4,000	121
Pipeline	1	19	19	19	19
System	10	9,455	0.25	9,400	946
Hose	14	1088	0.5	500	78
Tanker	2	7	2	5	4
TOTALS	63	14,912	0.1	9,400	237

Definitions:
- storage: storage containment, either on production installation or loading facility;
- Pipeline: pipelines between production, storage and loading facilities;
- System: loading buoy or facility (for example, pipework, swivels etc. but excluding storage);
- Hose: hose system from loading facility to tanker, including coupler; and
- Tanker: on board tanker.

The total volume loaded over the above systems between 1977 and end-1993 is approximately 1,700 million barrels, via 3,409 liftings. There are two large spills (>1,000 barrels) shown in Table 5.5-1 (4,000 bbl and 9,400 bbl). Therefore, the frequency of large spills was 2/1.7 or 1.2 spills per billion barrels offloaded.

5.5.2 Statoil Experience in the North Sea, 1979-1995

Statoil, the national oil company of Norway, has more than 15 years of experience with offshore loading in the North Sea, starting with the Statfjord A platform in 1979. Initially, the operation was based on an articulated loading platform (ALP) and modified conventional tankers, but has evolved into today's submerged turret loading (STL) system and a large fleet of specialized vessels. A Statoil paper on the subject (Breivik 1995) indicates that 5,000 cargos of crude oil, involving approximately 4 billion barrels, have been lifted by Statoil-operated tankers up to May 1994. In that time only two large spills have occurred: a 4000-barrel spill in 1980 and a 5,800-barrel spill in 1992. For some reason this latter spill, the second largest in Norwegian waters, was not referenced in the Breivik 1995 paper. According to the Oil Spill Intelligence Report - International Spill Statistics: 1992 (OSIR 1992), the spill took place on July 9, 1992 at the Statfjord offshore oil field, 140 km offshore at 61.00°N 002.00°E. The spill was suspected to be caused by workers who left a valve open while transferring oil from the platform to the oil tanker. This gives a spill frequency of $2/4 \times 10^9$ or 0.5 large spills per billion barrels offloaded.

In terms of smaller spills, Breivik (1995) indicates that only two have occurred, each less than 150 barrels.

5.5.3 Calculated Frequencies for White Rose

The existing data suggest that in the earlier days of offloading, the frequency of large spills was relatively high (2.3 spills per billion barrels produced) and very high for smaller spills, but has been reduced lately (to 0.5 large spills per billion barrels produced) as a result of better technologies. This change is clearly shown in the UK data from 1975 to 1993, where the number of 1.2 spills per billion barrels is about the average of the other two numbers. If it is assumed that the White Rose project will take advantage of these latest technologies and systems and operate them as well as Statoil, then a large-spill frequency of 0.5 spills /10^9 bbl produced might be a reasonable predictor. If not, a higher number, perhaps 2.3 spills/10^9 bbl, should be used. For want of further information, the middle number will be used (that is, 1.2 large spills (>1,000 bbl) for every billion barrels offloaded).

Therefore, for a production of 250 million barrels, the spill frequency prediction for White Rose becomes 1.2 x 0.250 = 0.30 large spills over the course of the 13-yr project, or about a one-in-three chance of occurrence. From the above records (and other experience, for example, the Shell Oil experience from 1982 to 1985 as reported in the Terra Nova EIS, Table 5.7-9, page 5-83), it is seen that the size of an offloading spill is likely to be less than 50 barrels (restricted to fluids in the offloading system). However, historical data indicate that if there is a large spill (>1,000 bbl), it is likely to be in the 5,000-barrel range, which is relatively small compared to the average size of other types of potential large spills. It is reasonable to expect much lower frequencies for the White Rose project, given substantial improvements in technology and/or practice in recent years, and the fact that regulatory requirements relating to oil spill prevention in the Canadian offshore are among the most stringent in the world.

5.6 AT-SEA OIL SPILLS FROM TANKERS AFTER LEAVING THE PRODUCTION FACILITY AND BEFORE ENTERING INTERNATIONAL SHIPPING LANES

Oil from the White Rose project will be transported ashore using shuttle tankers. After being loaded at the offshore production facility, the tankers will travel westward for a period before entering international shipping lanes. A map of shipping routes in the area is provided in Figure 4.3-5. The routes vary in terms of season. The maximum leg length is about 290 km and the minimum is about 110 km.

Once a tanker carrying White Rose oil enters an international shipping corridor it would be regulated by International Conventions.

This issue of the contribution of oil spill risk during shipping from the production site to the international shipping lanes was analyzed in a recent study by SL Ross (2000). The study was an update on a similar study performed for Petro-Canada on the Terra Nova project. The results are very similar, obviously, because of the similarity of the projects. The following is a summary of the results.

5.6.1 Spill Probability for Tankers in Initial Leg of Voyage From White Rose Facility to Land

In SL Ross (2000), it was determined from international statistics that the frequency of large, crude oil tanker spills (>1,000 bbl) occurring at sea (> 50 nautical miles from land) has been 1.7×10^{-8} spills per kilometre travelled.

The above frequency derived from worldwide statistics is used to predict the probability of oil spills from White Rose tankers during the at-sea portion of the journey to shore that is not in international shipping lanes, by using the number of kilometres involved in this part of the journey.

The following assumptions are made for this analysis:

1. The shuttle tankers will be of size 125,000 DWT or carry 900,000 barrels per journey.
2. The total amount of oil transported will be 250 million barrels.
3. The period of transportation will be 14 years.
4. The length of the initial voyage leg is 300 km (worst case).

From these statistics the total number of tanker trips over the 14-year lifetime of the project is $250 \times 10^6 / 0.9 \times 10^6$ = 278 voyages. Therefore the total distance travelled in the above-noted leg is 300 km x 278 voyages = 83,400 km.

The predicted spill frequency for this travel then is calculated to be 1.7×10^{-8} spills per km travelled x 83,400 km = 1.42×10^{-3} large spills (>1,000 bbl) over the 14 year lifetime of the project. This is equivalent to an annual large-spill frequency of 1.01×10^{-4} on average, or one such spill every 9900 years. This means that if the project were to continue forever, one could expect a large (>1,000 bbl) spill to occur in the initial leg every 9900 years. This is obviously a very low frequency or spill probability.

5.6.2 Summary and Discussion

This prediction may seem extremely low considering the public concern over major tanker spills, such as the *Exxon Valdez* spill in 1989 and the more recent *Braer, Sea Empress* and *Erika* tanker spills in Europe. It must be remembered, however, that these tanker spills, like most, occurred in restricted waters close to land. Of greater importance is the fact that large oil spills in general are extremely improbable events. In Canada, there has only been two large crude oil spills (larger than 1,000 barrels) in the past 25 years (one inland and one at sea: The *Athenian Venture* tanker spill (200,000 barrels or 27,000 tonnes) of crude oil spilled in late 1988 in the northwest Atlantic far off Canada during an inbound journey to Come-by-Chance).

The other reason that the calculated oil spill frequency value is so small is that the amount of White Rose oil that will be moved on an annual basis is relatively small compared to other areas and operations of the world where oil movements are very high and spill risks are correspondingly higher. For example, consider the high-traffic area, Valdez, Alaska, which was the site of the extremely large *Exxon Valdez* tanker spill in 1989 (involving approximately 230,000 barrels of crude oil). It can be calculated that the amount of oil moved at Valdez annually is more than 40 times higher than that planned for White Rose, and so the spill risk is that much higher. The point is that White Rose tanker spill frequencies are expected to be relatively low and the reason for this is that the amount of oil tanker traffic will be relatively small from a global perspective.

Finally, it should be remembered that the spill frequencies calculated were based on the assumption that the tankers used for White Rose would be as safe, but no safer, than the average tankers that have been used internationally over the past 15 years or so. In fact, the tankers will be much safer, and this would have the effect of reducing the calculated low spill frequencies to even lower values.

5.7 SUMMARY OF BLOWOUT AND SPILL FREQUENCIES

The calculated oil spill frequencies are summarized in Table 5.7-1. There is approximately a 11 percent chance that a platform-based spill larger than 50 barrels might occur over the course of the entire project. Spills less than 50 barrels in size might occur about once every five years, although their average size can be expected to be less than 10 barrels. The highest frequencies are obviously for small spills. Spills less than 1 bbl may occur with greater frequency than those in the size range of 1 to 49 bbl; such spills are usually fairly inconsequential.

Husky Oil will make every effort to ensure that operations are spill-free and as clean as possible and has a zero tolerance policy to all spills. Husky Oil's first response is prevention, but if a spill occurs, the personnel and equipment will be on site to respond.

The data from both small spills (1 to 49 bbl) and spills in the 50 to 999 bbl range are based on historical information. The situation has improved significantly over the years, because of better practices, more experience with routine operations and perhaps better regulatory control.

Large platform-based spills (>1,000 bbl) have about a 0.5 percent chance of occurring over the 13-yr course of the project. This is equivalent to a one-in-2,600 chance per year. This means that if the project were to continue forever, one platform-based spill larger than 1,000 barrels might occur every 2,600 years. Similarly, very large platform spills (>10,000 bbl) have a 0.2 percent chance of occurring over the 13-yr production period, or a one-in-7,100 chance per year.

The size of a potential tanker loading spill would be less than 50 barrels. The chance of a large (>1,000 bbl) tanker loading spill over the course of the entire project is approximately 30 percent. The annual probability is one in 43. This is relatively high, but the size of the spill is likely to be relatively small, that is, in the 5,000-barrel range.

For the three years of development drilling, the chances of an extremely large (>150,000 bbl) and very large (>10,000 bbl) oil well blowout from development drilling are about 0.08 and 0.16 percent, respectively. For similar blowouts from production activities and workovers that might occur over the 13-yr production period, the chances are 0.14 and 0.35 percent, respectively. This is equivalent to one extremely large oil well blowout (>150,000 bbl) for every 9,300 years of production and one very large oil well blowout (>10,000 bbl) for every 3,700 years of production. These predictions are based on worldwide blowout data and are strongly influenced by blowouts that have occurred in Mexico, Africa and the Middle East, where drilling and production regulations may be less rigorous. It is reasonable to expect even lower frequencies for the White Rose project than those calculated above, in view of the fact that no development drilling blowout spills larger than 10,000 barrels have occurred anywhere since 1980, suggesting a substantial improvement of technology and/or practice over the past 15 years.

Based on historical data, there could be a 4.8 percent chance of having a blowout involving gas only or gas with very small amounts of oil over the course of the 13-yr production period. In fact, however, the likelihood of a gas blowout at White Rose is much lower because all but two of the wells are oil targets, formation pressures are known and relatively low, and there is no drilling planned for White Rose in areas identified as having potential for shallow gas.

Table 5.7-1 Predicted Number of Blowouts and Spills for the White Rose Project over its 13-yr Lifetime

Event	Historical Frequency	White Rose Exposure	No. of Events	Annual Frequency	Annual Probability
BLOWOUTS					
1. Gas blowout during development drilling	2.4×10^{-3}/wells drilled	20 wells drilled over 3 yrs	4.8×10^{-2}	1.6×10^{-2}	one in 63
2. Blowout during production and workovers involving some oil discharge >1 bbl	6.5×10^{-5}/well-years	140 well-years	9.10×10^{-3}	7.0×10^{-4}	one in 1400
3. Development drilling blowout with oil spill > 10,000 bbl	7.8×10^{-5}/wells drilled	20 wells drilled over 3 yrs	1.56×10^{-3}	5.2×10^{-4}	one in 1900
4. Development drilling blowout with oil spill > 150,000 bbl	3.9×10^{-5}/wells drilled	20 wells drilled over 3 years	7.80×10^{-4}	2.6×10^{-4}	one in 3800
5. Production/workover blowout with oil spill > 10,000 bbl	2.5×10^{-5}/well-year	140 well-years	3.50×10^{-3}	2.7×10^{-4}	one in 3700
6. Production/workover blowout with oil spill > 150,000 bbl	1.0×10^{-5}/well-year	140 well-years	1.40×10^{-3}	1.1×10^{-4}	one in 9300
PLATFORM SPILLS (incl. blowouts)					
1. Oil spill > 10,000 bbl	1.3×10^{-5}/well-year	140 well-years	1.82×10^{-3}	1.4×10^{-4}	one in 7100
2. Oil spill > 1000 bbl	3.6×10^{-5}/well-year	140 well-years	5.04×10^{-3}	3.9×10^{-4}	one in 2600
3. Oil spill 50-999 bbl	8.0×10^{-4}/well-year	140 well-years	0.112	8.6×10^{-3}	one in 120
4. Oil spill 1-49 bbl	1.7×10^{-2}/well-year	140 well-years	2.38	1.8×10^{-1}	one in 5
TANKER LOADING SPILLS	1.2/billion bbls offloaded	0.250 billion bbls	0.3	2.3×10^{-2}	one in 43

5.8 FATE AND BEHAVIOUR OF WHITE ROSE OIL SPILLS

5.8.1 Introduction

The objective in this section is to assess the behaviour of large accidental oil spills that might occur during the White Rose Project (Project). The approach is to select a number of hypothetical "worst case" spills and describe their fate and behaviour in detail. These spill scenarios, involving various spill types and sizes, serve as the basis for subsequent effects assessment and spill control analysis.

Recent laboratory analysis of White Rose crude oil (S.L. Ross 2000) shows that the oil is of a waxy nature. This means that for some spill situations, the oil will form near-solid particles when spilled in cold water and persist for weeks and even months on the water surface. This attribute of the oil has a dramatic influence on both spill effect and cleanup potential. The purpose here is to explain the significance of the properties of the oil as determined by laboratory analyses, discuss the computer/ mathematical modelling that was conducted to estimate the behaviour and fate of selected hypothetical spills, and present the results of trajectory modelling that was done to assess the chances of spilled oil reaching shore from the White Rose development area.

5.8.1.1 Reference to the Hibernia and Terra Nova EISs

Offshore oil production is currently underway at the Hibernia site and installation of facilities at the Terra Nova site is in progress. The Hibernia, Terra Nova and White Rose developments are geographically quite close to each other. From an oil spill perspective, all three projects have some common attributes and some major differences. They are similar in terms of climatic conditions and kinds of accidents and oil spills that could occur, and much that was said about spills in the EISs for the Hibernia and Terra Nova projects applies to the White Rose project as well. Nonetheless, there are also important differences in the fate and behaviour of oil spills among the three sites. In order to compare these among the three sites, this section:

- summarizes the results and conclusions found in the relevant reports and documents produced for the Hibernia and Terra Nova projects;
- discusses the similarities and/or differences between the Project spill scenarios and those described for the Hibernia and Terra Nova projects;
- if the situation at White Rose is significantly different from those predicted for the other two sites, describe the subject in as much detail as is necessary to assess the current situation; and
- summarizes the White Rose results and compare the results with those that were found for Hibernia (Mobil Oil 1985; S.L. Ross 1984) and Terra Nova (Petro-Canada 1995; S.L. Ross 1995).

5.8.2 Selection of Oil Spill Scenarios

5.8.2.1 Introduction

This section discusses the nature of hypothetical, large oil spills from oil well blowouts and tanker loading accidents that could occur at the Project. The attributes of these spills are used in the next sections as a basis for describing the fate and behaviour of oil during a hypothetical accidental spill at White Rose.

The specific objective is to develop a manageable number of detailed large-spill scenarios that are illustrative of what might happen if a major spill occurred during the Project. In total, six scenarios have been selected. The reasoning behind the selection process is presented below.

Four scenarios were considered as the main conditions under which large spills could occur:

1. a continuous spill from a subsea oil-well blowout (blowout-subsea);
2. a continuous spill from an above-surface blowout (blowout-above-surface);
3. a batch spill from a ruptured container or loading hose leading to a discharge of oil over a short period of time (batch-transfer); and
4. a spill from a shuttle tanker that occurs over a short period of time (batch-tanker).

5.8.2.2 Spill Type, Size, and Duration

Analyses Conducted for the Hibernia and Terra Nova Projects

The oil spill scenarios that were used in the Hibernia and Terra Nova EISs are summarized in Tables 5.8-1 and 5.8-2, respectively.

Table 5.8-1 Summary of Hibernia Spill Scenarios

Spill Type	Source	Flow	Duration
Blowout	Subsea	30,000 BOPD* (4800 m^3/day)	90 d
		2,000 BOPD (318 m^3/day)	5 d
	Above-Surface	30,000 BOPD	90 d
		2,000 BOPD	5 d
Batch	Tanker	30,000 m^3	1 h
	Tanker	9,000 m^3	24 h
	Transfer	800 m^3	instantly
	Pipeline	300 m^3	1 h
* BOPD = Barrels of Oil Per Day			

Table 5.8-2 Summary of Terra Nova Spill Scenarios

Spill Type	Source	Flow	Duration
Blowout	Subsea	30,000 BOPD (4800 m^3/day)	90 d
		30,000 BOPD	45 d
		45,000 BOPD (7150 m^3/day)	7 d
	Above-Surface	45,000 BOPD	7 d
Batch	Transfer	800 m^3	Instantly
* BOPD = Barrels of Oil Per Day			

White Rose Scenarios

The scenarios that were selected for modelling for White Rose are shown in Table 5.8-3.

Table 5.8-3 Summary of White Rose Spill Scenarios

Spill Type	Source	Flow	Duration
Blowout	Subsea	20,250 BOPD (3218 m^3/day)	7 d
		4,170 BOPD (663 m^3/day)	45 d
	Above-Surface	15,900 BOPD (2525 m^3/day)	7 d
Batch	Transfer	5,000 bbl (800 m^3)	instantly
	Tanker	63,000 bbl (10,000 m^3)	instantly
	Tanker	188,700 bbl (30,000 m^3)	instantly
* BOPD = Barrels of Oil Per Day			

Blowouts

The methodology used here to select and size the various White Rose blowout scenarios was based on one originally developed for use in the Beaufort Sea by Adams Pearson Associates (1991). This method was used to calculate oil escape paths, flowrates and incident durations using specific White Rose drilling and production characteristics as input (W. Smink, pers. comm.). These calculations produced the blowout rates and durations shown in Table 5.8-3.

Batch Spills

The transfer spill scenario of 800 m^3 of oil is the same as that selected for analysis during the Hibernia and Terra Nova EISs. The 10,000 m^3 batch tanker spill is similar to that used in the Hibernia EIS (Mobil Oil 1985; S.L. Ross 1984) and is the largest planning volume specified in the *Canada Shipping Act's* Response Organizations Standards (Fisheries and Oceans 1995). The 30,000 m^3 worst-case batch spill was selected because this spill size was also considered in the Hibernia EIS.

Environmental Conditions Assumed for Scenarios

For each scenario, calculations of oil slick behaviour and fate were made for environmental conditions occurring during two seasons. Average monthly temperatures and winds for the area shown in Table 5.8-4 are taken from Sections 2.1 and 2.4. For the seasonal generic scenarios modelled at the White Rose site, a winter spill was defined as occurring with air and water temperatures of 2ºC and winds of 42.5 km/h (12 m/s); a summer spill had air and water temperatures of 11ºC and winds of 32 km/h (9 m/s).

Table 5.8-4 Environmental Data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave. Air T (ºC)	0	-1	1	2	4	7	11	14	12	9	5	2
Ave. Water T (ºC)	1	0	0	1	3	8	11	14	13	10	7	4
Ave. Wind (km/h)	42.5	42.5	37	33	32	32	32	28	32	36	39	42.5

A 10,000 m^3 tanker spill was modelled to assess the effect of seasonal wind velocities on spill fate and trajectory at the White Rose site. The model used a wind data set collected over 40 years from 1958 to 1997 (Kalnay et al. 1996). The spatial wind data covers the Grand Banks area in a grid composed of blocks that are 0.625° latitude by 0.833° longitude, and provides surface wind velocities, at 6-h intervals, for each block. Monthly average air and water temperatures from Table 5.8-4 were used in the model. A 10,000 m^3 batch release was modelled for every day of the year, for the 40 years of available wind data, and each spill was tracked for 30 days.

5.8.3 White Rose Oil Properties and General Spill Behaviour

5.8.3.1 Introduction

Many publications describe the general behaviour of marine oil spills. However, certain Grand Banks crude oils, including White Rose oil, do not behave like conventional oils because of their waxy nature. Initial studies of Grand Banks crude oils (Mobil Oil 1985; S.L. Ross 1984; S.L. Ross 1985) did not fully consider the behaviour of waxy crude oils. The comprehensive study by S.L. Ross and DMER (1988) addressed and mathematically analyzed the peculiar behaviour of these oils.

The main purpose of this section is to describe the spill-related properties of White Rose crude oil and how this oil is likely to behave if spilled in the Grand Banks marine environment. For illustrative purposes, this discussion is set against a brief discussion of the behaviour of "conventional" crude oil spills.

5.8.3.2 Spill-Related Properties of White Rose Crude Oils

The important spill-related physical properties of the White Rose crude used for spill scenario prediction purposes in this document are listed in Table 5.8-5. The crude oil that is modelled is from the White Rose L-08 well.

Table 5.8-5 Properties of White Rose Crude as Compared to Other Grand Bank Crudes

Property	Oil Type			
	Hibernia[a]	Terra Nova[b]	Hibernia[c]	White Rose[d]
API gravity	30.4	32.5	35	33
Density, kg/m^3 @ 15ºC	874	862	850	859
Viscosity, (mm^2/s) @ 25ºC	25	18.2	30	38
Air/Oil Interfacial Tension (mN/m)	27.2	29	28.8	30
Oil/Seawater Interfacial Tension (mN/m)	21	29.6	9.2	25
Pour Point, (ºC)	9	12	-6	18
Flash Point, (ºC)	14	< 21	12.5	<0
Emulsion Formation Tendency and Stability @ 1ºC and 15ºC	very stable	Very stable	not stable	very stable
Aqueous Solubility (g/m^3) in Saltwater @ 22ºC	17	18.78	not measured	not measured

a) B-27 well (S.L. Ross and DMER 1988 and S.L. Ross 1984).
b) K-08 well DST.4 (S.L. Ross 1985).
c) Hibernia as produced (S.L. Ross 1999). Note that this oil was very different (less waxy, low stability emulsions) than the oil tested in 1984.
d) White Rose L-08.

It is recognized that the White Rose area will produce oils with a range of properties, that these oils will be blended during the production process, and that the oils produced by individual wells will change over time. For the purpose of this study, it is assumed that the properties of White Rose crude L-08 are representative of the oil that will be produced at White Rose.

The viscosity and pour point of the White Rose crude are higher than any of the other Grand Banks crude oils analyzed (Table 5.8-5). The pour point of the White Rose crude is significantly higher than the average summer water temperature. The implications of this on the behaviour of spills are discussed in Section 5.8.3.3.

Another key spill-related property of all of the White Rose and Terra Nova crude oils analyzed to date is that they form very stable water-in-oil emulsions when spilled, even when the oil is freshly spilled (referred to as “fresh”). The formation of stable emulsions has implications for spill behaviour, particularly survival time of oil on the surface. Another point of interest is that the Hibernia oil tested in 1999 is less waxy (lower pour point) and has a much lower tendency to form stable emulsion than the samples taken from one of the early exploration wells (B-27) in the mid-1980s.

The remainder of the spill-related physical properties of the White Rose crude are typical of a medium-gravity crude oil.

5.8.3.3 Comparison of White Rose and "Conventional Oil" Spill Behaviour

When oil is spilled at sea it is subject to several so-called weathering processes, including: drifting (advection), spreading, evaporation, natural dispersion and dissolution of oil in water, and water-in-oil emulsification.

Drifting

General

Drifting, or advection, is the process by which surface slicks move away from the site of a spill under the influence of water currents. These currents usually combine residual current movement and wind-induced surface movements whose velocities are approximately 3.5 percent of the wind velocity. In nearshore marine waters, the movement of oil slicks is also affected by tidal currents, river outflow, and longshore currents.

White Rose

The properties of the spilled oil do not greatly affect the drifting process, hence, spills of White Rose oil will move as any spilled oil would. The subject of oil spill drifting is covered in more detail in Section 5.8.5 on White Rose spill trajectories.

Spreading

General

Numerous models of oil spreading behaviour and its dependence on oil properties and environmental conditions have been developed over the last three decades. Recent models relate the properties of the oil (density, viscosity, and interfacial tension) to its spreading on calm water. Most models also include an oceanic diffusion term to describe spreading behaviour under more realistic sea conditions.

Conventional, low-viscosity oils flow easily over water and exhibit a high rate of spreading. For example, a spill of 1,000 m^3 (6,300 barrels) can produce a slick with a total area of about 10 km^2 after one or two days of spreading. This is equivalent to an average slick thickness of 0.1 mm. The surface oil is usually not a uniform, thin sheet of oil. It is usually composed of thick patches that are thicker than 1 mm and that contain most of the spill volume, surrounded by very thin sheens that are approximately 10 m or 0.001 to 0.01 mm in thickness.

White Rose

White Rose crude will not spread in the same way as the conventional oil described above. The pour point of the crude is above the average water temperature year-round. This means that when White Rose crude is spilled, it will gel and not flow or spread. This will likely result in blowouts generating streams of small gelled droplets of oil (S.L. Ross and DMER 1988) that do not coalesce to form a slick. These individual droplets may, however, agglomerate to form larger particles. Batch spills of White Rose crude will likely form thick (>1 cm) layers of gelled oil that are "fractured" into metre-sized mats of oil by wave action (S.L. Ross and DMER 1988). The interfacial tensions of the White Rose crude are such that these mats will continue to generate a thin sheen of oil around them as they travel.

Evaporation

General

Evaporation is one of the most intensively studied and predictable processes. It is known that the evaporation rate of an oil slick is controlled or affected by the: (1) temperature; (2) surface area of the oil in contact with air; (3) thickness of the oil; (4) wind speed; and (5) concentration and vapour pressure of the individual components of the oil. Many models predict oil evaporation rates following an approach developed by Professor D. Mackay at the University of Toronto (for example, Stiver and Mackay 1983), where an overall "mass transfer coefficient" for evaporation is first determined experimentally. In these models, the volume or mass fraction of oil evaporated is related to an exposure coefficient (combining time, oil volume and area, and the mass transfer coefficient to the atmosphere) and to the vapour pressure-concentration behaviour of the oil. The unique aspect of this approach is that it permits the results from a variety of laboratory evaporation experiments to be extrapolated to actual environmental conditions with a relatively high degree of confidence. The results of this approach in predicting the evaporative loss from a 1 mm slick of conventional crude oil (density = 0.84 g/cm^3) as a function of sea state are indicated in Table 5.8-6.

Table 5.8-6 Evaporation of Conventional Crude Oil Slicks as a Function of Sea State

Beaufort Sea State	Oil Loss (Percent)			
	Exposure = 6 hrs		Exposure = 24hrs	
	5°C	15°C	5°C	15°C
Medium (2-3)	23	32	28	37
High (4-6)	26	35	29	38

White Rose

For waxy oils such as the White Rose oil, there are additional resistances to mass transfer that curtail evaporation. These relate primarily to the development of internal resistances to the movement of molecules of volatile species to the surface of the slick and their escape from the surface of the slick into the air. When a waxy oil evaporates and loses volatile components, the wax molecules begin to precipitate from solution and the oil begins to gel. Once a certain resistance to flow is created by the precipitated waxes, the oil reaches its pour point. In other words, evaporation increases the pour point of oil until it equals, then exceeds the pour point at ambient air or water temperature. At this point, it becomes more difficult for components to migrate from the inside of the slick to its surface; as such, the surface and near-surface of the slick begin to lose volatile components at a rate faster than that of the interior. This eventually results in a "skin" of waxy-like material forming on the surface of slicks or droplets of waxy oil. This "skin" further restricts the movement of molecules from the interior of the oil to the atmosphere. Experiments have indicated that, at a point when the pour point exceeds ambient temperature by approximately 15ºC, these resistances to evaporation become significant (S.L. Ross and DMER 1988).

Another important feature of White Rose spills that relates to evaporation is the formation of non-spreading droplets during blowouts. The surface area to volume relationship is different for a sphere than for a flat plate (such as, a slick). For an infinite flat plate, the ratio of area to volume is the inverse of the thickness (as used in Stiver and Mackay (1983) to develop the rate of evaporation of a slick); for a sphere (or droplet) the ratio of area to volume is 6/diameter. Although the full surface area of the droplet is not exposed to air because it is floating in water, the use of 6/diameter appears to fit evaporation data from droplets on water adequately (S.L. Ross and DMER 1988). This may be because the volatile species can migrate from the droplet into water and from there into the air nearly as fast as they can migrate directly into the air.

In summary, waxy oils evaporate more slowly than conventional oils and can form waxy "skins" that virtually encapsulate the volatile components of the oil within. The result is that the oil maintains its volume with little loss through evaporation or natural dispersion, and tends to persist for long periods on the surface because of its viscous nature.

Natural Dispersion and Dissolution

General

The dispersion and dissolution of oil in the water by natural forces is an important process controlling the long-term fate of oil slicks at sea. In conjunction with evaporation, this process reduces the volume of oil on the water surface, thereby influencing the potential extent of surface and shoreline contamination.

Dispersion and dissolution are physical processes by which oil and the more soluble lower molecular weight hydrocarbons move from the slick into the water column. For conventional crude oil spills, oil droplets are dispersed relatively easily from the slick into the water column by waves. The larger of these droplets, which are buoyant, resurface quickly and rejoin the slick. The smaller droplets remain in suspension in the water column. The lighter, more water-soluble hydrocarbons partition from these droplets into the water phase. Clouds of the entrained dissolved and particulate oil then spread horizontally and vertically by diffusion and other long-range transport processes. Thus, the oil concentrations in the water column under the slick are the result of the competing processes of entrainment of oil into the water column, which increases the concentration, and horizontal and vertical diffusion and transport of hydrocarbons which decreases the oil concentration in the water column.

The net flux rate of oil from a slick (small particles and dissolved hydrocarbons) into the water column will vary greatly depending on the properties of the spilled oil and mixing energy (Delvigne 1985; 1987; Mackay et al. 1980).

White Rose

Significant concentrations of dispersed oil under White Rose crude oil spills are unlikely because the oil is resistant to natural dispersion. This is because of the gelled nature of White Rose crude at ambient temperatures, particularly droplets from blowouts, and the strong tendency of mats of the oil to emulsify. Modelling suggests that the only significant source of dispersed oil for White Rose spills will be from the sheens generated by thicker slicks or droplets.

Emulsification

General

When most crude oils are spilled at sea, they tend to form water-in-oil emulsions. Emulsification occurs in the presence of mixing energy such as that provided by wave action. During emulsification, seawater is incorporated into the oil in the form of microscopic droplets. This water intake results in a significant increase in the bulk volume of the oil (usually up to a four or five-fold increase) and a marked increase in fluid viscosity. Spills of some conventional crude oils will start to form emulsion within a few minutes of being spilled, and will form a highly viscous and stable emulsion within hours. Most refined petroleum products do not emulsify. Many crude oils do not begin to emulsify immediately, but will emulsify after the oil has evaporated to some extent.

White Rose

As noted previously in Table 5.8-5, White Rose crude oil will emulsify readily at ambient temperatures when it is fresh. The exception to this is the case of small gelled oil droplets generated by a blowout.

These droplets are too small to be penetrated by the mixing action of waves (they are merely tossed about by the waves) and do not readily coalesce to form a slick.

Sedimentation

General

Some of the oil that becomes entrained into the water may become associated with suspended particulate matter that ultimately may settle to the seabed. The amount and concentrations of hydrocarbons that reach the seabed near a spill site appear to be a function of the amount of oil entrained into the water, the amount and nature of particulate matter suspended in the water, water depth, and the speed of subsurface water movements.

White Rose

Considering the low rate of natural dispersion expected for spills of White Rose crude, sedimentation is unlikely to occur to a measurable degree; thus there is little chance of much of the oil settling on the seabed.

5.8.3.4 Behaviour of Oil Well Blowouts Near the Source

Marine oil spills that result from offshore oil well blowouts will behave very differently than will instantaneous batch spills. This is because spills from blowouts are produced in a much different manner than batch spills, and their initial layout and properties are different. The selected hypothetical spills in this analysis are mostly blowout-related. Blowouts with particular reference to the situation at White Rose are described briefly in the following sections. For a more detailed treatment of the subject see S.L. Ross (1984).

There are two basic kinds of offshore oil-well blowouts. The first is a subsea blowout, during which the drilling platform moves off site or is destroyed. In this case, the oil is discharged from a point on the seabed in an uncontrolled manner and rises through the water column to the water surface. An example of this kind of oil-well blowout was the 1979 Ixtoc-1 blowout in the Bay of Campeche in Mexico (Ross et al. 1979). The other possibility is an above-surface blowout in which the platform maintains its position during the accident, because it is undamaged or bottom-founded, and the oil discharges into the atmosphere from some point on the platform above the water surface, and subsequently falls on the water at some distance downwind. Examples of this kind of oil well blowout were the 1977 Ekofisk blowout in the North Sea (Audunson 1980) and the Uniake blowout off Nova Scotia (Gill et al. 1985).

Subsea Blowouts

General

Oil-well blowouts, both subsea and above-surface, generally involve two fluids, namely crude oil and natural gas. The volume ratios of these two fluids are a function of the characteristics of the fluids, and of the pressure and temperature of the geological reservoir. The natural gas, being a compressible fluid under pressure at reservoir conditions, provides the driving force for an uncontrolled blowout. As the well products flow upward, the gas expands, finally exiting the well-head at extremely high velocities. At this point the oil makes up only a small fraction of the total volume of flow.

The high velocity at the well-head exit generates a highly turbulent zone that is responsible for the fragmentation of the oil into droplets ranging from 0.5 to 2.0 mm in diameter (Dickins and Buist 1981). Because water is also entrained in this zone, a rapid loss of momentum occurs a few metres from the discharge location. At this point, buoyancy becomes the driving force for the remainder of the plume. In this region, the gas continues to expand due to reduced hydrostatic pressures. As the gas rises, oil and water in its vicinity are entrained in the flow and carried to the surface.

Although the terminal velocity of a gas bubble in stationary water is only approximately 0.3 m/s, velocities in the centre of blowout plumes can reach 5 to 10 m/s due to the pumping effect of the rising gas in the bulk liquid. That is, the water surrounding the upward moving gas is entrained and given an upward velocity, which is then increased as more gas moves through at a relative velocity of 0.3 m/s. When the plume becomes fully developed, a considerable quantity of water containing the oil droplets is pumped to the surface.

In the surface zone, the rising water and oil flow away from the centre of the plume in a radial layer. At the surface, the oil, if it were fluid, as would be the case for conventional oils, coalesces in this outward flow of water and spreads at a rate much faster than ordinary spill spreading rates. The resulting slick takes on a hyperbolic shape when subjected to a natural water current, with its apex pointed up-current. The dimensions of the slick can be estimated using mathematical models. These are briefly described in Section 5.8.4.

White Rose

White Rose blowouts would behave as described above except that the oil droplets would not re-coalesce to form a slick, but would remain as discrete droplets. This is because the pour point of the crude exceeds ambient water temperatures. These oil droplets would, however, generate a sheen on the surface.

Above-Surface Blowouts

General

Oil released during a blowout from an offshore platform above the water surface will behave differently than that from a subsurface discharge. The gas and oil will exit at a high velocity from the well-head and will be fragmented into a jet of fine droplets. The height that this jet rises above the release point will vary depending on the gas velocity, oil particle size distribution and the prevailing wind velocity. The fate of the oil and gas at this point is determined by atmospheric dispersion and the settling velocity of the oil particles. The oil will "rain" down, with the larger droplets falling closer to the release point. If the gas is blowing through the derrick or some other obstruction, oil droplets will agglomerate on the obstruction(s) and increase in diameter. During their time in the air, the droplets evaporate, and may do so quite quickly due to their high surface area to volume ratio and warm temperature.

For conventional oils, a slick will form on the water surface, and its dimensions can be estimated with the use of a mathematical atmospheric deposition model. Generally, slicks resulting from an above-surface blowout are much thicker and narrower than slicks produced by subsea blowouts and, therefore, are easier to control and recover using conventional spill cleanup equipment.

White Rose

In the case of an above-surface blowout at the White Rose oilfield, it has been assumed that the oil spray hits the derrick and other structural steel on the rig and the fine oil mist agglomerates to form 0.75 mm diameter droplets. These droplets rain down onto the water surface and form a slick (the flow rate of the well and atmospheric deposition calculations indicate that the droplets would fall on top of each other forming a slick, as opposed to discrete droplets as is the case for a subsea blowout). The degree of evaporation experienced by the droplets during their time in the air is such that the initial oil slick will be extremely viscous and have a pour point well above ambient temperatures.

5.8.4 Modelling and Description of Selected Oil Spill Scenarios

This section focuses on the behaviour of the selected hypothetical spills. The trajectory of the spilled oil is discussed in Section 5.8.5.

Of particular interest is the behaviour of large blowout spills at and near the platform because it is here where spill control measures can be most effective. Also important are the distribution and "stickiness" of the oil particles on the surface as a function of time because these factors will determine impacts on birds at the water surface.

The predictions used in this section were generated using a state-of-the-art spill behaviour and fate model described in Petro-Canada (1995). Average seasonal temperatures and winds were used for the scenario descriptions. Time-varying winds were used for the trajectory analysis in the following section. The properties of White Rose crude oil (see Table 5.8-5) were used in the model. Six scenarios were developed (refer to Table 5.8-3) and spill behaviour predictions made for each in both summer and winter conditions.

All scenarios were modelled for 30 days. The assumed accuracy of current spill modelling techniques is such that confidence in the results is inversely proportional to the duration of the model run. There is a high degree of confidence in modelled results during the initial phases of a spill model, versus later stages. Confidence in the results drops precipitously when considering the modelled long-term behaviour and fate of spilled oil. A few weeks after a spill, White Rose oil will certainly be in the form of widely distributed particles and patches that will diffuse and dilute as time passes. The long-term rate of diffusion is poorly understood and limits usefulness of the model.

5.8.4.1 Blowout Scenarios

In this section the near-source behaviour of an above-surface blowout is described followed by descriptions of two subsea blowouts. The blowout scenarios describe the behaviour and characteristics of a single "slicklet" of oil. A slicklet is a defined portion of oil moving away from the blowout source. The quantity of oil and initial thickness of the slicklet are dependent on the release conditions of the blowout (for example, subsea vs. above-surface, wind speed, etc.). The slick widths and thicknesses reported for the following blowouts refer to those of the individual slicklets.

15,900 BOPD Above-Surface Blowout Lasting Seven Days in Summer

A blowout occurs on the on-site rig, resulting in a discharge of 15,900 BOPD of White Rose crude oil with a gas-to-oil ratio (GOR) of 130 m^3/m^3 (730 ft^3/bbl) (Table 5.8-7). The platform and rig are not damaged and remain in position throughout the seven-day blowout period. The gas and oil exit at the drill floor (25 m above the water surface) at high velocity and the oil exits as small diameter droplets. These droplets are shot upward by the jet of gas, hit the derrick and agglomerate to a median size of about 0.75 mm in diameter. This median drop size was used for all surface blowout modelling and is based on model calibration using data from the Ekofisk blowout. These droplets rain down on the water beside the rig. Most of the droplets fall onto the water surface within about 300 m of the rig in a 70 m wide band and coalesce to form a slick. Throughout the seven days required to stop the blowout, the air and water temperatures average 11ºC. The surface water current is 0.25 m/s.

Table 5.8-7 Spill Behaviour for 15,900 BOPD Above-Surface Blowout During Summer and Winter

Time Since Spill		Season	Total Slicklet Width (m)	Slicklet Thick. (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	Percent Evaporated	Percent Dispersed
Hours	Days								
0	0	S	70	6.8	0	7,600	17.9	4.8	0
		W	85	6.3	0	131,000	17.4	3.1	0
1	0.04	S	79	6.7	46	50,000	18.3	6.0	0.01
		W	86	6.3	60	Semisolid	17.5	3.4	0
6	0.25	S	154	6.5	74	654,000	19.4	9.2	0.01
		W	97	6.2	75	semi-solid	17.9	4.9	0
12	0.5	S	230	6.3	75	semi-solid	20.0	11.2	0.015
		W	114	6.1	75	semi-solid	18.5	6.5	0
24	1	S	350	6.2	75	semi-solid	20.7	13.3	0.02
		W	147	5.9	75	semi-solid	19.4	9.2	0
48	2	S	534	6.0	75	semi-solid	21.5	15.4	0.04
		W	200	5.7	75	semi-solid	20.5	12.6	0
120	5	S	890	5.6	75	semi-solid	22.5	18.3	0.17
		W	310	3.8	75	semi-solid	22.0	16.8	0
240	10	S	1250	4.7	75	semi-solid	23.4	20.7	0.70
		W	440	3.6	75	semi-solid	23.0	19.5	0.01
480	20	S	1590	3.6	75	semi-solid	24.1	23.1	2.8
		W	610	3.4	75	semi-solid	23.9	21.8	0.03
720	30	S	1720	2.9	75	semi-solid	25.0	24.4	5.7
		W	730	3.3	75	semi-solid	24.4	23.2	0.07

The slick at the source is approximately 70 m wide and 6.8 mm thick. The oil making up the slick has lost approximately 5 percent of its volume to evaporation when the oil droplets were in the air. The resulting oil has a viscosity of 7,650 mPas and a pour point of 18ºC (higher than the average summer temperature). Within the first hour of exposure to the environment, the oil has formed an emulsion containing 50 percent water. The water content increases to 75 percent after 12 h. The emulsion is estimated to be semi-solid within about 12 h.

The extremely high viscosity values reported in this document should be used only as an indicator that these oils will, in most instances, be very viscous, semi-solid, and thus persistent. Models for the prediction of some aspects of spills of highly viscous oil do not exist. Where viscosities have been estimated to be greater than about 1 million mPas, by the simple model used (Mackay et al. 1980), the oil has been reported to be semi-solid.

As the oil drifts from the site, wave action breaks the slick up into viscous mats of oil that move away from each other under the influence of oceanic turbulence. Because the oil is thick and viscous it survives for a very long time at sea. After 30 days, 70 percent of the discharged oil is still on the surface. The makeup of this oil will depend on environmental conditions over this period. It is likely that after 30 days, the oil will be broken into small waxy balls spread over a large area, with the oil particles separated by large expanses of water.

15,900 BOPD Above-Surface Blowout Lasting Seven Days in Winter

This blowout is identical to that described in the previous scenario, except that it occurs in winter when winds are higher at 12 m/s and temperatures are colder at 2°C (Table 5.8-7). The higher winds cause the oil to remain in the air for a longer period of time. They fall out within 400 m of the rig in a slick that is 85 m wide. The cold temperature result in slightly less initial evaporation (3 percent by volume) but a higher initial viscosity (131,000 mPas) than in summer. As with the summer scenario, the oil emulsifies rapidly (60 percent water content in one hour) to form extremely persistent mats of emulsion. Even with the higher average winter winds and higher sea-states, 75 percent of the oil discharged is estimated to remain on the sea surface after 30 days.

20,250 BOPD Subsea Blowout Lasting Seven Days in Summer

In this scenario (Table 5.8-8), the blowout occurs through the casing shoe and the oil and gas flow to the seabed through a fracture in the rock. The oil flow rate is 20,250 BOPD and the GOR is 130 m^3/m^3 (730 ft^3/bbl). The fluids erupt from the seabed and the gas breaks the oil up into small droplets that are carried to the surface with water being entrained by the gas. Throughout the seven days before the well base collapses and seals off the flow, the water and air temperatures are 11ºC and the wind is 9 m/s.

At the surface, the oil drops themselves do not spread to form a slick because the ambient temperature is below the oil's pour point. The entrained water flow creates a hyperbolic-shaped slick that extends 250 m up-current of the gas boil zone which is located at the focus of the hyperbole and is 1,570 m wide down stream of the gas boil. The droplets of oil are widely scattered in this zone and occupy only approximately 10 percent of the surface area. By the time the slick has spread to 1,570 m, the oil droplets have lost 10 percent of their volume to evaporation; this increases to 15 percent after 6 h and 20 percent after 24 h, up to a maximum of about 30 percent after several days.

Table 5.8-8 Spill Behaviour for 20,250 BOPD Subsea Blowout During Summer and Winter

Time Since Spill		Season	Total Slicklet Width (m)	Particle Diameter (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	Percent Evaporated	Percent Dispersed
Hours	Days								
0	0	S	1,570	1.06	0	3,370	16.5	0	0
		W	1,170	1.06	0	77,000	16.5	0	0
1	0.04	S	1,570	1.02	0	20,500	19.7	10.0	0
		W	1,180	1.05	0	145,000	17.6	3.6	0
6	0.25	S	1,580	1.0	0	63,500	21.6	15.7	0
		W	1,190	1.02	0	513,000	19.8	10.4	0
12	0.5	S	1,580	0.99	0	99,000	22.4	17.9	0
		W	1,195	1.01	0	semi-solid	21.1	14.1	0
24	1	S	1,600	0.98	0	155,000	23.2	20.0	0
		W	1,205	0.99	0	semi-solid	22.2	17.2	0
48	2	S	1,625	0.97	0	243,000	24.0	22.1	0.01
		W	1,225	0.98	0	semi-solid	23.1	19.8	0
120	5	S	1,700	0.96	0	440,000	25.0	24.7	0.04
		W	1,275	0.97	0	semi-solid	24.3	22.7	0
240	10	S	1,800	0.95	0	690,000	25.8	26.7	0.1
		W	1,350	0.96	0	semi-solid	25.1	24.8	0

The slick spreads slowly from its initial width to reach 1,630 m after 48 h. The fresh oil viscosity at summer temperature is 3,400 mPas. Evaporation raises the viscosity of the droplets, which do not emulsify, to 99,000 mPas after 12 h and 155,000 mPas after 24 h. Evaporation also slightly reduces the diameter of the droplets, from 1.1 mm initially to 0.98 mm after 24 h.

The droplets are extremely persistent, losing only 30 percent of their volume after 30 days, primarily through evaporation. As discussed earlier, little or no dispersion is expected.

20,250 BOPD Subsea Blowout Lasting Seven Days in Winter

This scenario is identical to the previous one, except that it occurs in winter with higher winds (12 m/s) and colder air and water temperatures (2ºC). The upstream extent of the slick is 190 m from the gas boil and is slightly less than in summer and its downstream width at 1,170 m is also less (Table 5.8-8). This is due to the higher wind-driven water current. The colder temperatures also slow the evaporation rate of the droplets, even in higher winds.

The fresh oil viscosity at the average winter temperature is 77,000 mPas. Evaporation raises the viscosity of the droplets, which do not emulsify, to a semi-solid state within 12 h. As in the summer case, the oil is very persistent, with only 28 percent lost in 30 days at sea, with little or no dispersion expected.

4,170 BOPD Subsea Blowout in Summer

This scenario is similar to the previous subsea blowout, except that the oil and gas flowrates are lower (Table 5.8-9). As a result, larger 5.1 mm oil droplets are generated at the seabed and the upstream extent (190 m) and downstream width (925 m) are less than those estimated for the 20,250 BOPD scenario.

Table 5.8-9 Spill Behaviour for 4,170 BOPD Subsea Blowout During Summer and Winter

Time Since Spill		Season	Total Slick Width (m)	Particle Diameter (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (ºC)	Percent Evaporated	Percent Dispersed
Hours	Days								
0	0	S	924	5.1	0	3,370	16.5	0	0
		W	696	5.1	0	77,000	16.5	0	0
1	0.04	S	927	5.0	0	8480	18.1	5.2	0
		W	698	5.07	0	124,000	17.3	2.7	0
6	0.25	S	940	4.9	0	23,500	19.9	10.6	0
		W	706	5.0	0	288,000	18.8	7.4	0
12	0.5	S	950	4.9	0	32,000	20.7	12.9	0.01
		W	715	4.9	0	480,000	19.7	10.1	0
24	1	S	975	4.8	0	56,000	21.44	15.1	0.02
		W	730	4.9	0	semi-solid	20.6	12.8	0
48	2	S	1,015	4.8	0	88,000	22.2	17.4	0.04
		W	760	4.8	0	semi-solid	21.5	15.3	0
120	5	S	1,130	4.7	0	159,000	23.3	20.3	0.12
		W	840	4.8	0	semi-solid	22.6	18.4	0.01
240	10	S	1,290	4.7	0	249,000	24.0	22.5	0.33
		W	960	4.7	0	semi-solid	23.4	20.7	0.02
480	20	S	1,580	4.6	0	391,000	24.8	24.7	1.0
		W	1,160	4.7	0	semi-solid	24.1	23.0	0.07
720	30	S	1,840	4.6	0	509,000	25.3	26.0	2.04
		W	1,340	4.6	0	semi-solid	24.6	24.3	0.15

The oil droplets lose 5 percent of their volume to evaporation in the first hour, 13 percent after 12 h and 17 percent after 48 h. The droplets do not emulsify, but the evaporative loss increases their viscosity to 23,500 mPas in 6 h and 56,300 mPas in 24 h.

The droplets are extremely persistent. Only 30 percent of their volume is lost over 30 days, primarily through evaporation.

4,170 BOPD Subsea Blowout in Winter

The only differences between this scenario and the previous one are higher winds (12 m/s) and lower air and water temperatures (2ºC). The higher winds generate faster surface currents that result in a narrower slick (696 m) with a smaller upstream extent (110 m) (Table 5.8-9). The colder temperatures reduce the evaporation rate slightly when compared to the summer scenario. The oil droplets lose 3 percent of their volume to evaporation in the first hour, 10 percent by 12 h and 15 percent after 48 h. The droplets do not emulsify, but the evaporative loss increases their viscosity to 288,000 mPas in 6 h and to a semi-solid state within 24 h. The oil is much more viscous than in summer due to the colder air and water temperatures.

The droplets are extremely persistent. Only 25 percent of their volume is lost over 30 days, primarily through evaporation.

5.8.4.2 Batch Transfer Spill Scenarios

800 m^3 Batch Transfer Spill in Summer

As a result of an offloading accident, 800 m^3 of White Rose crude oil are spilled instantaneously. The water temperature is 11ºC and the wind speed is 9 m/s. The oil gels shortly after it enters the water and begins to break up into mats, but because it is fresh, the mats generate a sheen. The oil also begins to emulsify, reaching 46 percent water content after 1 h. At this point, its viscosity is 18,900 mPas and the mats are 37 mm thick (Table 5.8-10). The oil is fully emulsified within 12 h and has a water content of 75 percent, a viscosity of 245,000 mPas and a mat thickness of 77 mm. Evaporation of this oil will be slow due to the thickness of the mats and properties. Evaporation loss is only 3.6 percent after 12 h and 5.4 percent after 24 h. The oil will not naturally disperse due to its high viscosity and thickness. Only 16 percent of the oil will be removed from the surface after 30 days. At this time the mats can be expected to be broken up into patches, particles and waxy balls and be spread over an area of at least 140 km^2.

The large slick thicknesses reported for the weathered batch spills are nominal values only. It is likely that heavy seas will eventually break-up the emulsion mats into smaller and smaller pieces that will have "diameters" ranging from a few millimetres to centimetres. The existing model treats the thick oil as a contiguous slick, with a predicted thickness because models for the prediction of the breakup of gelled mats are not available. The slick thicknesses reported in the batch spill table, especially those after 10 days or so, are maximum possible values (that is, conservative estimates) that would occur only if relatively calm conditions were experienced over the entire 30-day simulation period.

800 m^3 Batch Transfer Spill in Winter

The main difference between this scenario and the previous one is the higher emulsion viscosity due to the colder air and water temperatures. These cause a more rapid emulsification, a slightly smaller slick size due to reduced sheen production, and slower evaporation than for the summer transfer spill. Full emulsification and a semi-solid state is reached within 6 h (Table 5.8-10). Approximately 85 percent of the oil will remain on the water surface after 30 days (15 percent evaporation loss) and will be in the form of widely spaced patches and particles of weathered emulsion spread out over an area of approximately 72 km^2.

Table 5.8-10 Spill Behaviour for 800 m^3 Batch Transfer Spill During Summer and Winter

Time Since Spill: Hours	Time Since Spill: Days	Season	Total Slick Width (m)	Slick Thick. (mm)	Water Content (%)	Viscosity (mPas)	Pour Point (°C)	Percent Evaporated	Percent Dispersed
0	0	S	680	20	0	3,370	16.5	0	0
		W	680	20	0	77,000	16.5	0	0
1	0.04	S	730	37	37	18,900	16.6	0.5	0
		W	710	49	49	semi-solid	16.6	0.3	0
6	0.25	S	980	77	74.8	188,000	17.2	2.2	0
		W	865	79	75	semi-solid	17.0	1.6	0
12	0.5	S	1,250	77	75	245,000	17.6	306	0
		W	1,035	78	75	semi-solid	17.2	2.4	0
24	1	S	1,710	75	75	337,000	18.2	5.4	0
		W	1,340	77	75	semi-solid	17.6	3.6	0
48	2	S	2,480	74	75	492,000	18.8	7.5	0.01
		W	1,870	75	75	semi-solid	18.2	5.5	0
120	5	S	4,290	70	75	semi-solid	19.8	10.5	0.03
		W	3,140	73	75	semi-solid	19.1	8.4	0
240	10	S	6,600	66	75	semi-solid	20.6	12.7	0.12
		W	4,800	70	75	semi-solid	19.9	10.8	0
480	20	S	10,300	59	75	semi-solid	21.4	15.1	0.58
		W	7,420	65	75	semi-solid	20.7	13.2	0.02
720	30	S	13,300	52	75	semi-solid	21.9	16.6	1.5
		W	9,600	61	75	semi-solid	21.2	14.7	0.06

5.8.4.3 Tanker Spill Scenarios

10,000 and 30,000 m^3 Tanker Spills in Summer

As a result of a tanker accident, 10,000 or 30,000 m^3 of White Rose crude are spilled instantaneously. The air and water temperature is 11ºC and the wind speed is 9 m/s. The behaviour of this oil (evaporation, emulsification, property changes, etc.) will be similar to the summer transfer spills discussed above but with higher volumes of oil released, slick areas will be larger (Table 5.8-11). As previously discussed, this oil "gels" when released in temperatures below about 15°C. The thick gelled oil does not spread like conventional oil and also produces the thin sheen surrounding the oil at a much slower rate. This results in more persistent oil. After 30 days, the particles of oil from the 10,000 and 30,000 m^3 spills will be spread over areas of approximately 160 and 180 km^2, respectively.

Table 5.8-11 Spill Behaviour for 10,000 and 30,000 m^3 Tanker Spills During Summer and Winter

Time Since Spill		Season	Total Slick Width for (10,000m³) (m)	Total Slick Width for (30,000m³) (m)	Slick Thick (mm)	Emulsion Water Content (%)	Viscosity (mPas)	Pour Point (°C)	Percent Evap.	Percent Dispersed
Hours	Days									
0	0	S	2,390	4,145	20	0	3370	16.5	0	0
		W	2,390	4,145	20	0	3366	16.5	0	0
1	0.04	S	2,430	4,175	37	46	18,900	16.6	0.48	0
		W	2,415	4,160	49	60	77,000	16.6	0.33	0
6	0.25	S	2,600	4,320	77	74	188,000	17.2	2.2	0
		W	2,520	4,250	79	75	semi-solid	17.0	1.6	0
12	0.5	S	2,795	4,480	77	75	245,000	17.6	3.6	0
		W	2,640	4,350	78	75	semi-solid	17.2	2.4	0
24	1	S	3,150	4,790	76	75	337,000	18.2	5.4	0
		W	2,865	4,540	77	75	semi-solid	17.6	3.7	0
48	2	S	3,790	5,350	74	75	491,000	18.8	7.4	0
		W	3,280	4,900	76	75	semi-solid	18.2	5.4	0
120	5	S	5,410	6,805	72	75	semi-solid	19.8	10.4	0.01
		W	4,370	5,860	73	75	semi-solid	19.1	8.4	0
240	10	S	7,610	8,860	70	75	semi-solid	20.6	12.7	0.02
		W	5,880	7,240	71	75	semi-solid	19.9	10.8	0
480	20	S	11,200	12,300	67	75	semi-solid	21.4	14.9	0.07
		W	8,380	9,590	69	75	semi-solid	20.7	13.2	0
720	30	S	14,300	15,270	66	75	semi-solid	21.8	16.3	0.17
		W	10,500	11,635	68	75	semi-solid	21.2	14.4	0.01

10,000 and 30,000 m^3 Tanker Spills in Winter

The behaviour of this oil will be similar to the tanker spills discussed above. The colder water temperature (2ºC vs. 11ºC) cause the emulsion to be more viscous and have slightly slower evaporation and dispersion rates than in summer (Table 5.8-11).

The values for oil pour point, water content, viscosity, evaporation, and dispersion are essentially the same for both the 10,000 and 30,000 m^3 spills. The slick widths for the two spill volumes will be different, as seen in Table 5.8-11. After 30 days, the particles of oil from the 10,000 and 30,000 m^3 spills will be spread over areas of approximately 90 and 110 km^2, respectively.

5.8.5 Spill Trajectories

5.8.5.1 Introduction

The previous section discusses what happens to the oil when it is released. This section discusses where it goes. The spilled oil will be moved by currents and wind until it very slowly disperses in the water and diffuses on the surface to low concentration, or contacts land. As noted in the previous sections, White Rose oil spills will tend to be highly persistent, and survival times of weeks and even months are not inconceivable.

5.8.5.2 Previous Hibernia and Terra Nova Analyses

For the Hibernia EIS, Seaconsult (1984) modelled potential slick movement at Hibernia using 30 years (1945 to 1975) of meteorological and oceanographic data. Results showed that a slick from a large surface blowout would move over large portions of the Grand Banks during its calculated survival time, while a worst-case batch spill would pass over a much smaller area, despite a longer indicated survival time. Modelled trajectories generally showed that under the prevailing wind and current regimes, most slicks would tend to move offshore, to the east and northeast. Only during the months of November, December, January, and March, was there a possibility of shoreline contact (Table 5.8-12). Of the 11,000 trajectories run during the analyses, only 11 reached land.

Table 5.8-12 Impact and Closest Point of Approach to Shoreline for Hibernia Oil Slick Models

Month	Impact				Closest Approach	
	Number of Trajectories Reaching Shore	**Trajectories Reaching Shore (%)**	**Earliest Time to Reach Shore (d)**	**Shoreline Location**	**Time from Start of Spill (d)**	**Distance From Shore (km)**
January	4	0.43	9.8	Southeast Avalon	-	-
February	0	-	-	-	8.5	51
March	2	0.22	29	Southwest Burin	-	-
April	0	-	-	-	29	76
May	0	-	-	-	10.7	150
June	0	-	-	-	19	150
July	0	-	-	-	16	144
August	0	-	-	-	10.2	194
September	0	-	-	-	74	103
October	0	-	-	-	13.2	134
November	5	0.56	17.2	Southeast Avalon	-	-
December	1	0.11	27.2	Southeast Avalon	-	-

The following assumptions and methods were used by Seaconsult for the Hibernia EIS. AES geostrophic wind data were used for the years between 1946 and 1975. These data were adjusted to better represent surface winds, which are needed in oil spill trajectory modelling. Surface wind was derived by multiplying the geostrophic value by 0.88 and rotating the direction by 20E anti-clockwise. The water currents used were the IIP data set of 1979. Slick trajectories were estimated by the vector addition of the IIP water currents and 3.5 percent of the adjusted AES wind speed rotated 10E clockwise to account for Coriolis effect. Scenarios were run for a maximum of 180 days or until the slick left the study area or reached land.

Subsequent to the Hibernia work, an updated IIP water current grid and additional AES wind data became available. The IIP water current data for 1995 and the AES wind data from 1946 to 1989 were used for the Terra Nova trajectory analysis (S.L. Ross 1995). The trajectories were run for 30 days, until they hit land, or they moved out of the study area. The number of slicks predicted to reach land from this modelling is presented in Table 5.8-13. These results are very similar to those found in the earlier Hibernia study. The percentage of the spills that reached land in the Terra Nova modelling was approximately 0.2 percent. The modelling for Hibernia indicated that 0.1 percent of trajectories would reach land. Contact happened primarily in winter months in both analyses.

Table 5.8-13 Terra Nova Spill Trajectories Reaching Land

Month/Year ***(Days During the Month When Slicks Released)***	**Time to Shore** **(Hrs)**
March 1951 *24, 25, 26, 27*	342 to 474
April 1978 *1, 2, 3, 4, 5, 6, 7, 8, 9*	534 to 672
January 1979 *18, 19, 20, 21, 22, 23, 24*	432 to 552
March 1987 *9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20*	492 to 702
Total Slicks Reaching Land = 32 Total Scenarios Run = 15,900	

5.8.5.3 White Rose Spill Trajectories

A more recent and improved historical wind data set has become available since the Terra Nova trajectory modelling was done. This data set was prepared by the U.S. National Centres for Environmental Prediction (NCEP) and the U.S. National Centre for Atmospheric Research (NCAR) (Kalnay et al. 1996). A 10,000 m^3 batch release has been modelled for every day of the year, for the 40 years of available wind data, and each spill was modelled for 30 days. The 10,000 m^3 spill was selected for analysis because it was the same size used in similar modelling for the Terra Nova and Hibernia assessments and it is the largest spill size used for planning purposes under the *Canada Shipping Act's* Response Organizations Standards (Fisheries and Oceans 1995). Monthly average air and water temperatures from Table 5.8-4 were used in these simulations.

A total of 14,600 trajectories were modelled in this analysis. It was found that there were no shoreline contacts from any of the spill trajectories originating at the White Rose site using the upgraded wind data and the IIP water current data for 1995.

The trajectory data has been further processed, on a monthly basis, to identify the likelihood of a slick reaching a given area on the Grand Banks. A 1 km x 1 km grid was overlain on the Grand Banks. The slick movements for all spills released in a given month of the year, for the 40 years of data, were tracked to identify what percentage of the spills entered each grid cell. The movements of 1,240 slicks (31 days x 40 years of wind data) were combined to generate the figures for months with 31 days. A total of 1,200 spill trajectories were used to generate the figures for those months with 30 days and 1,120 trajectories for the month of February. The results for each month of the year are presented in Figures 5.8-1 through 5.8-12.

Figure 5.8–1 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in January

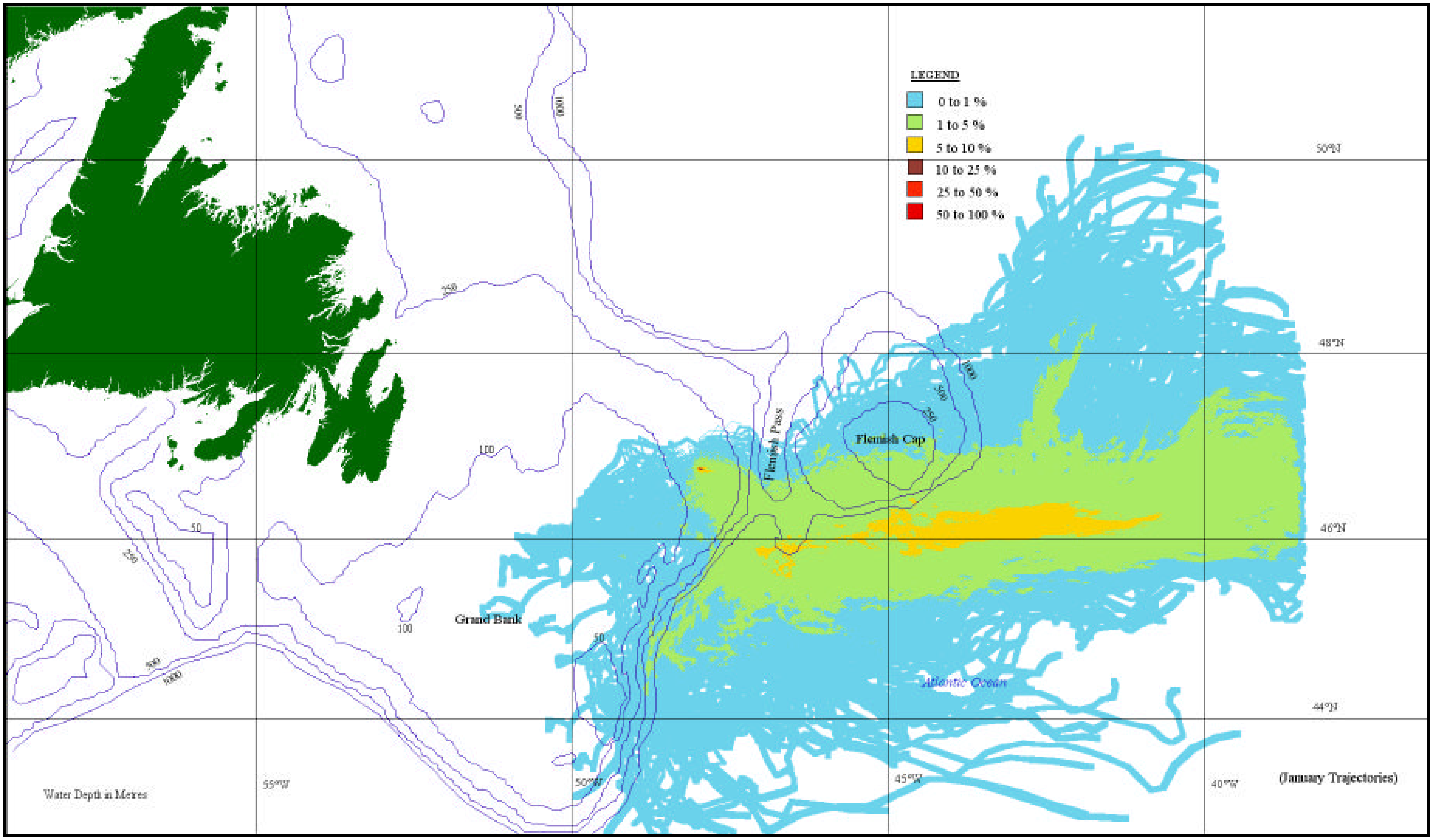


Figure 5.8–2 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1120 Spill Trajectories in February

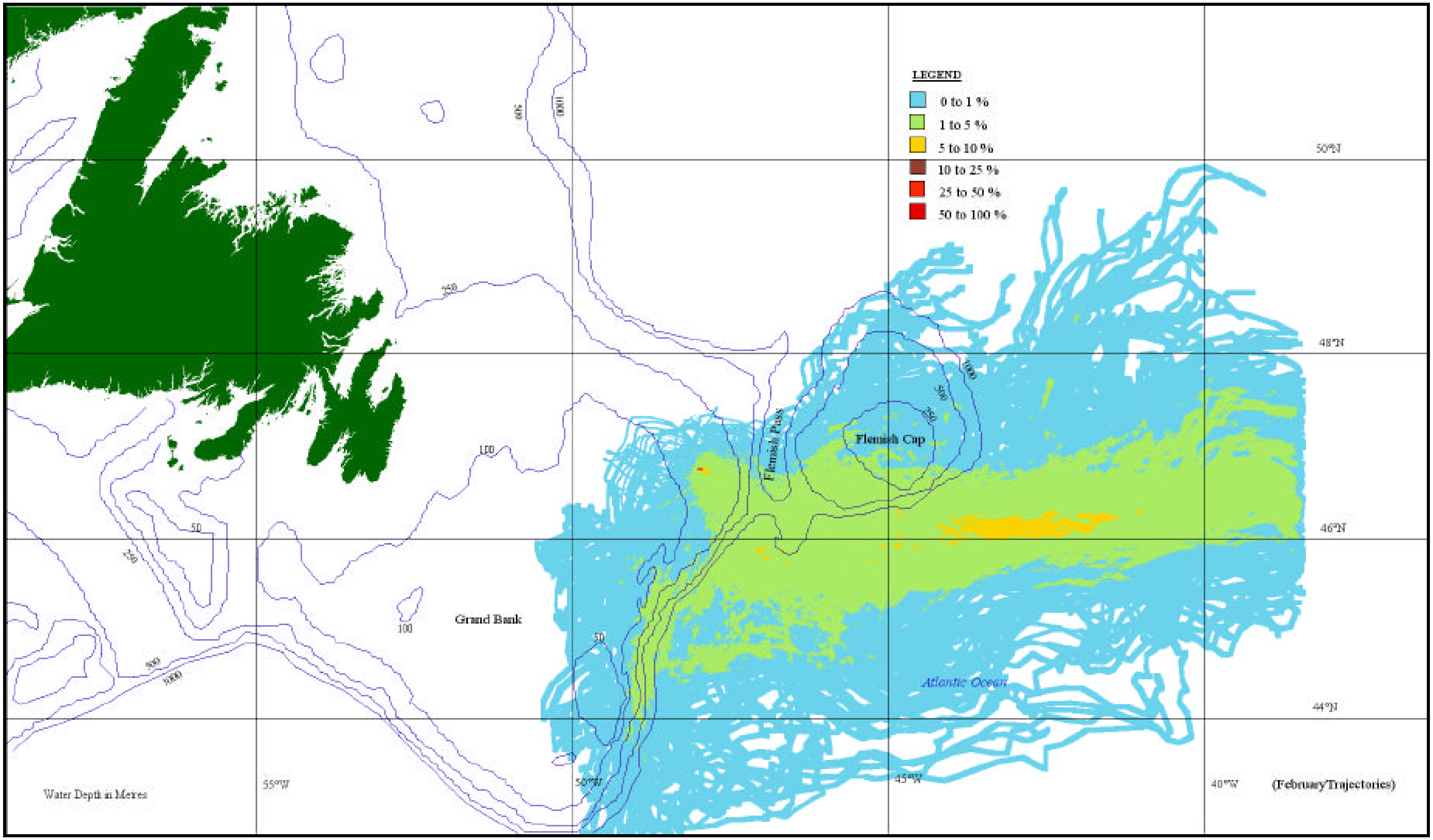


Figure 5.8–3 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in March

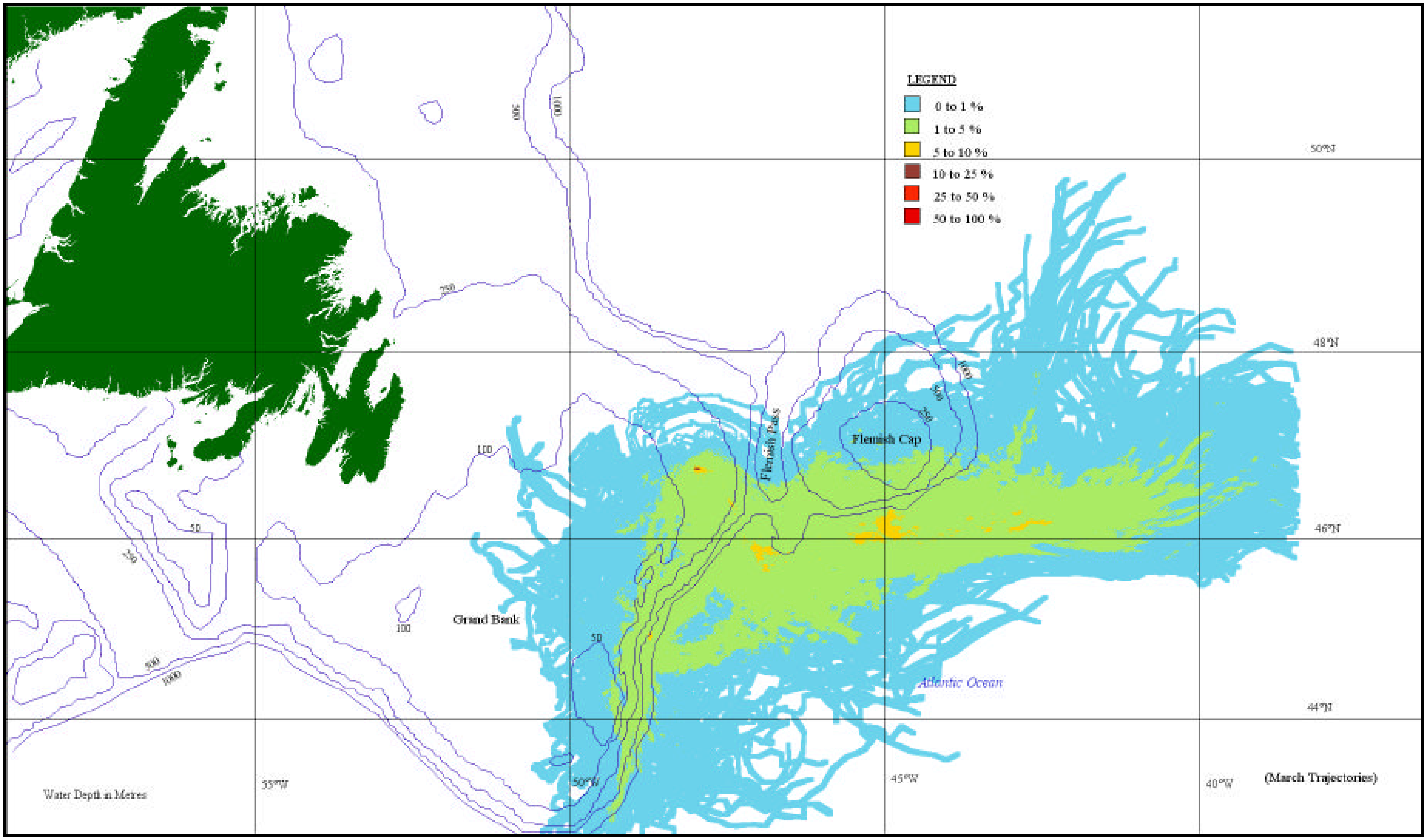


Figure 5.8–4 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1200 Spill Trajectories in April

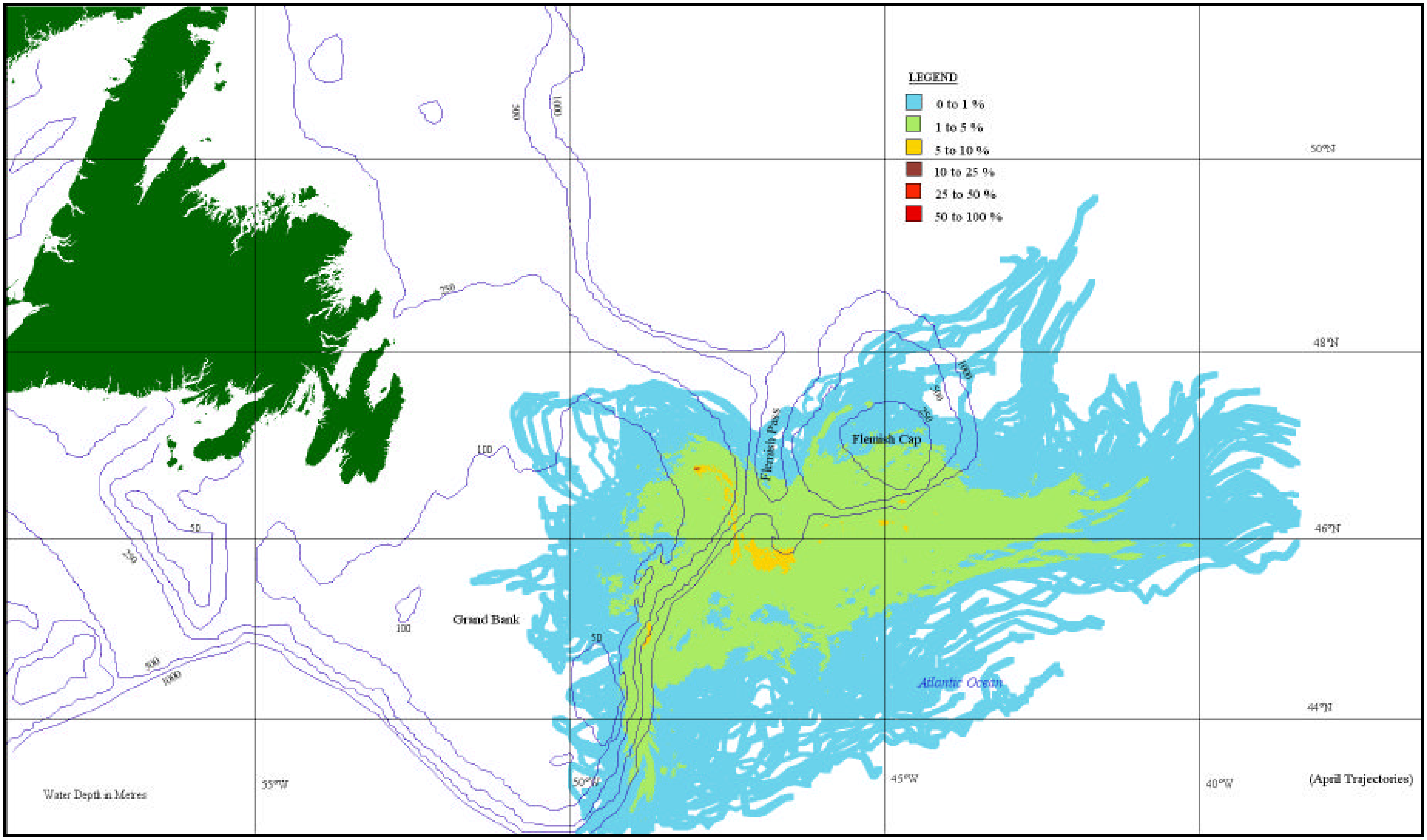


Figure 5.8–5 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 spill trajectories in May

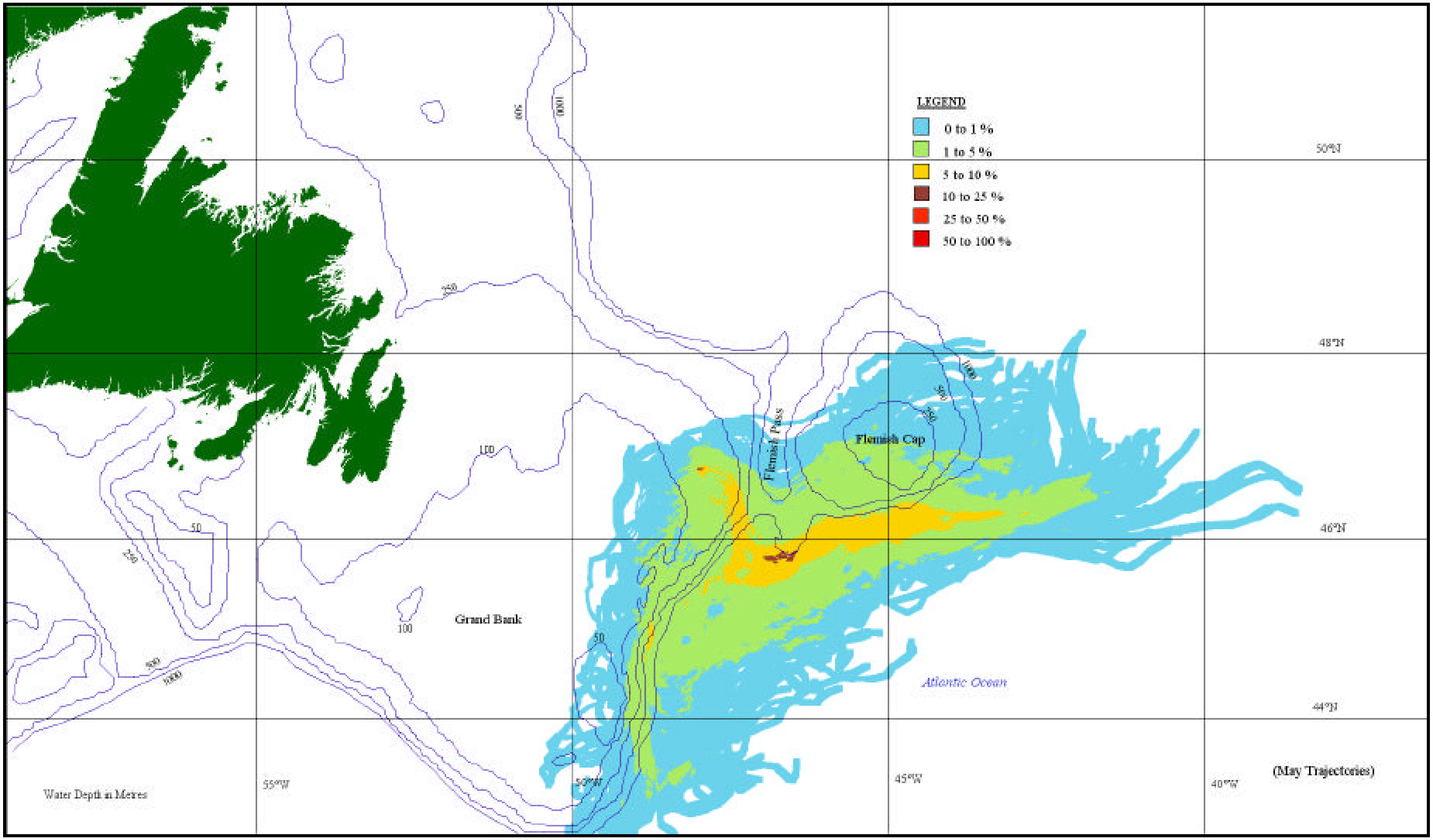


Figure 5.8–6 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1200 Spill Trajectories in June

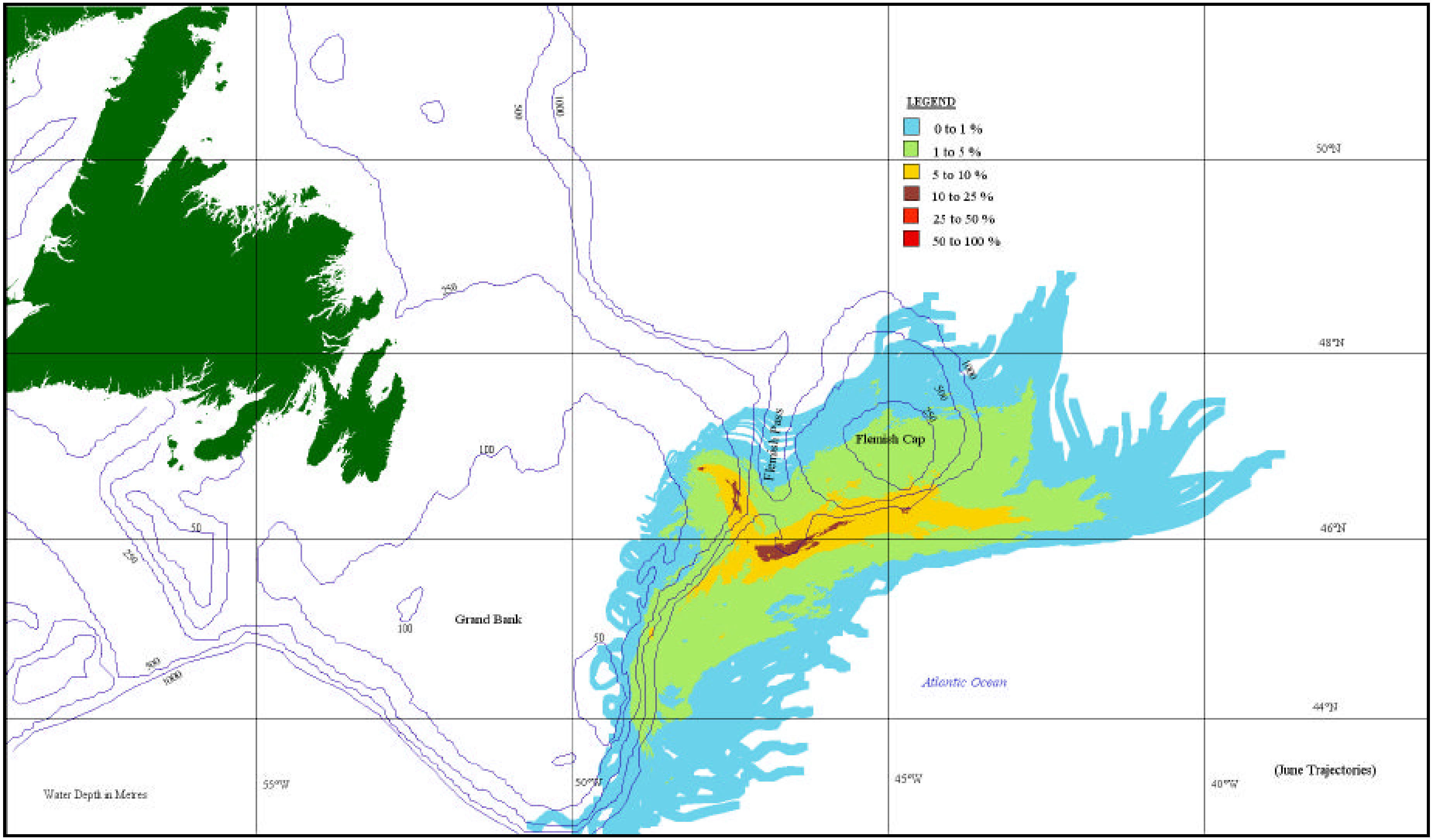


Figure 5.8–7 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in July

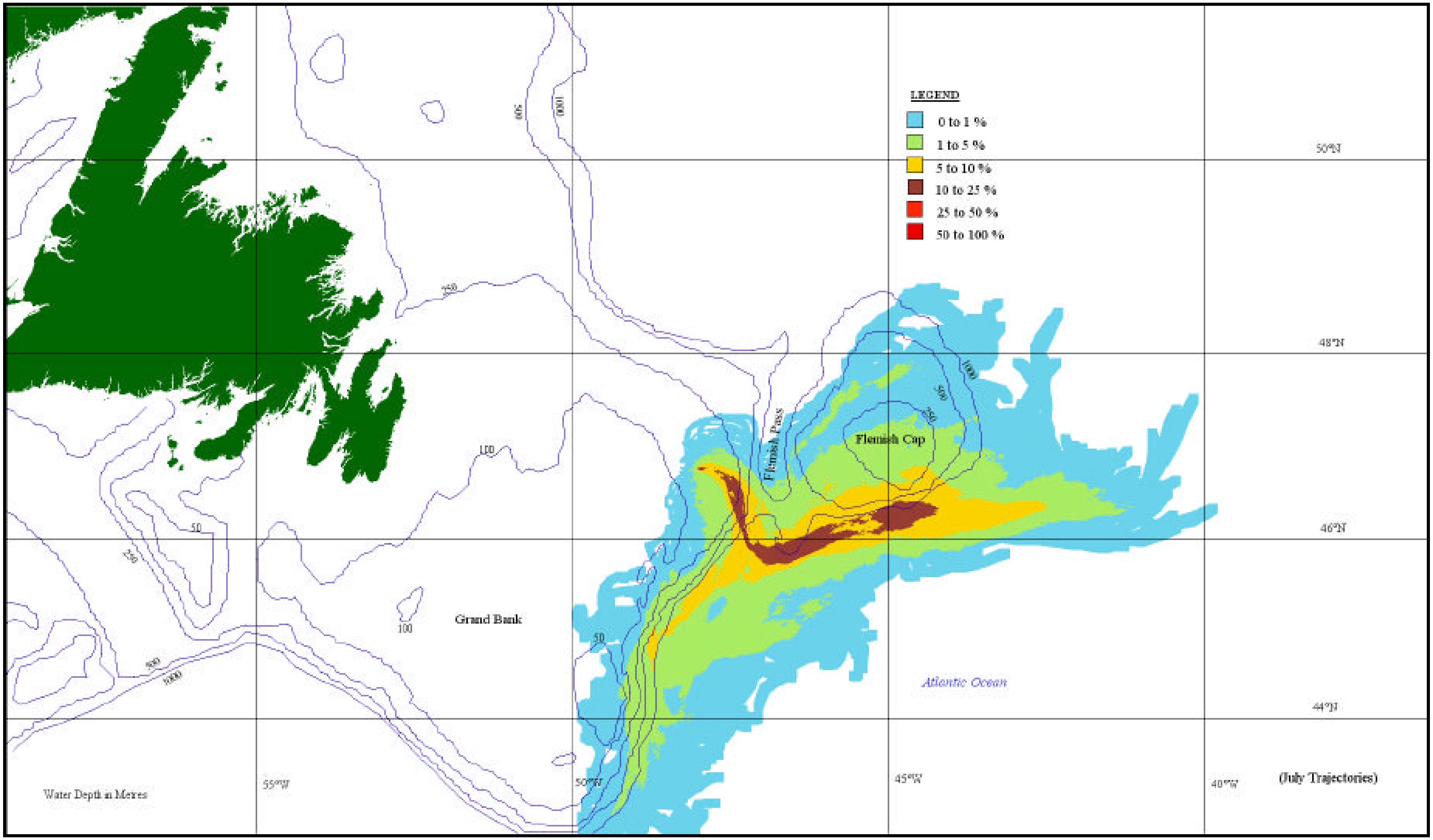


Figure 5.8–8 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in August

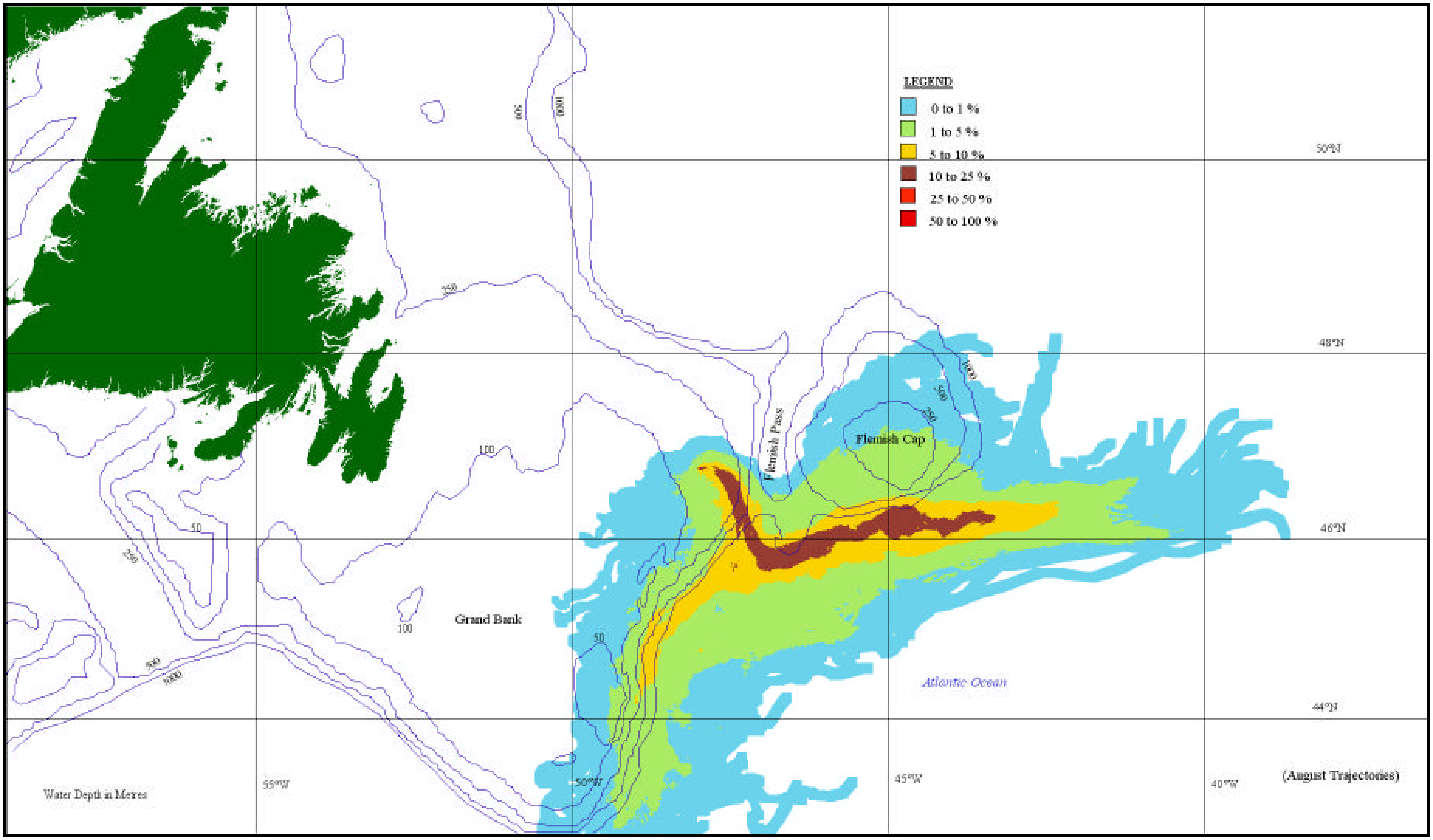


Figure 5.8–9 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1200 Spill Trajectories in September

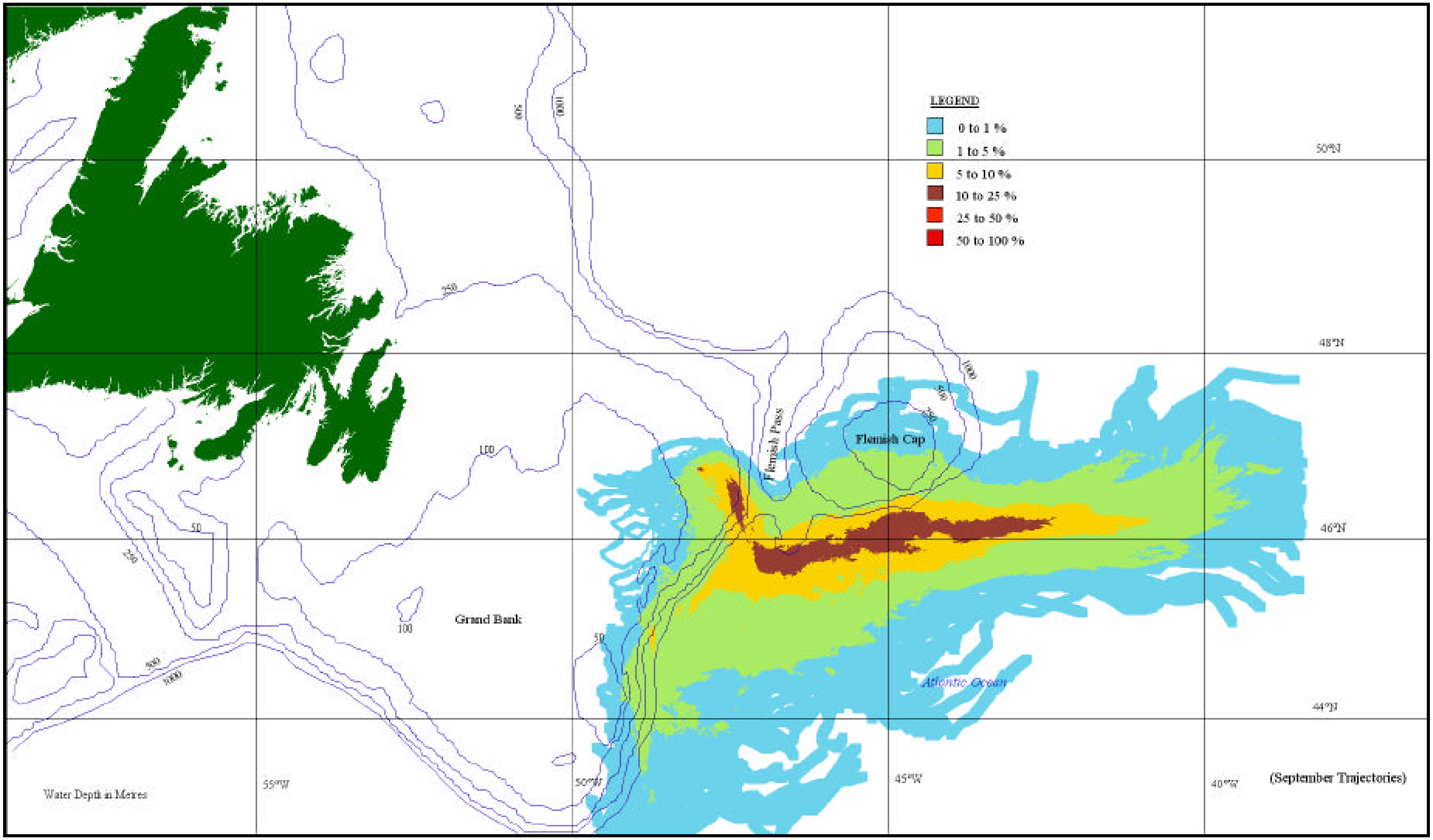


Figure 5.8–10 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in October

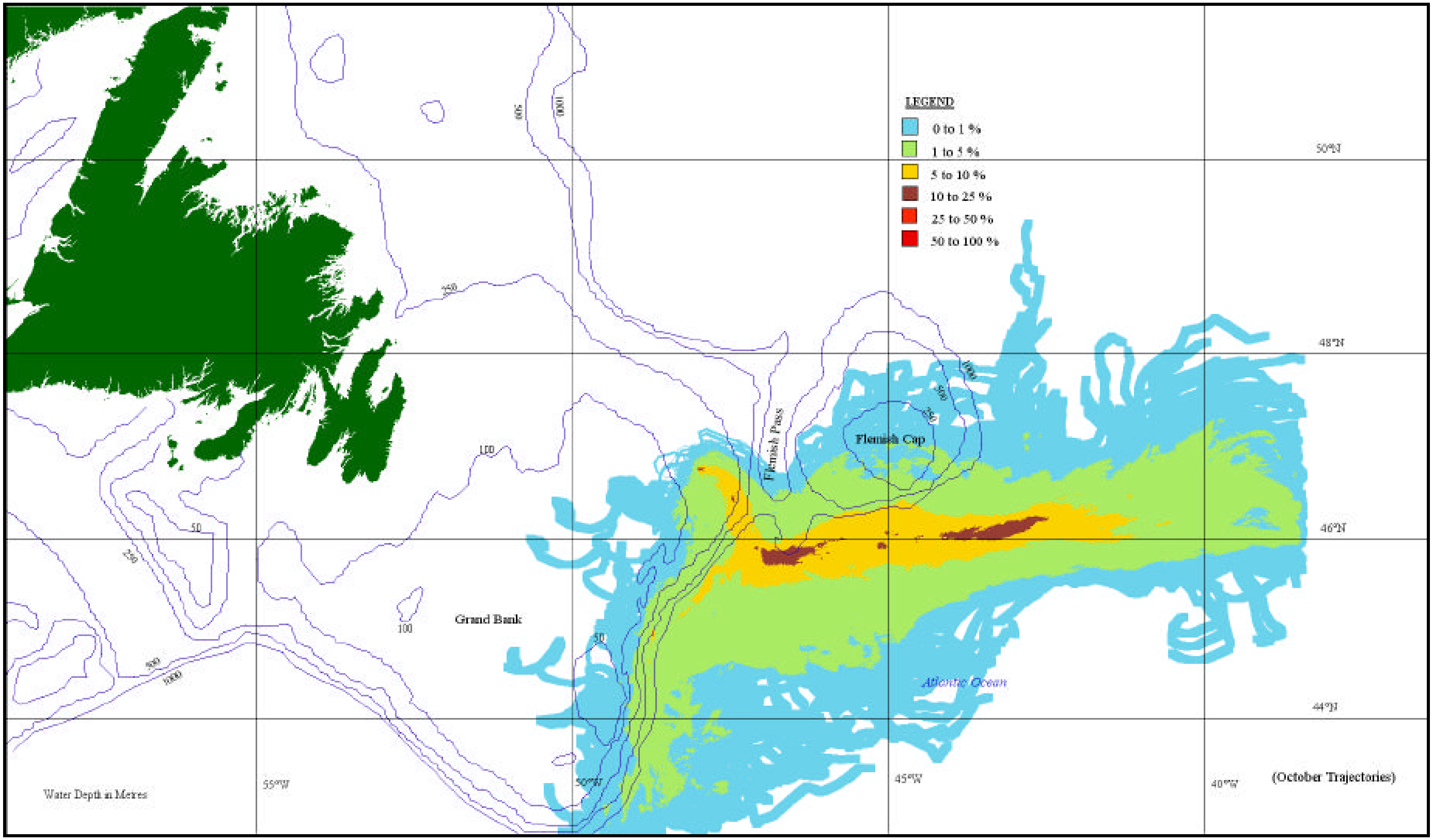


Figure 5.8–11 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1200 Spill Trajectories in November

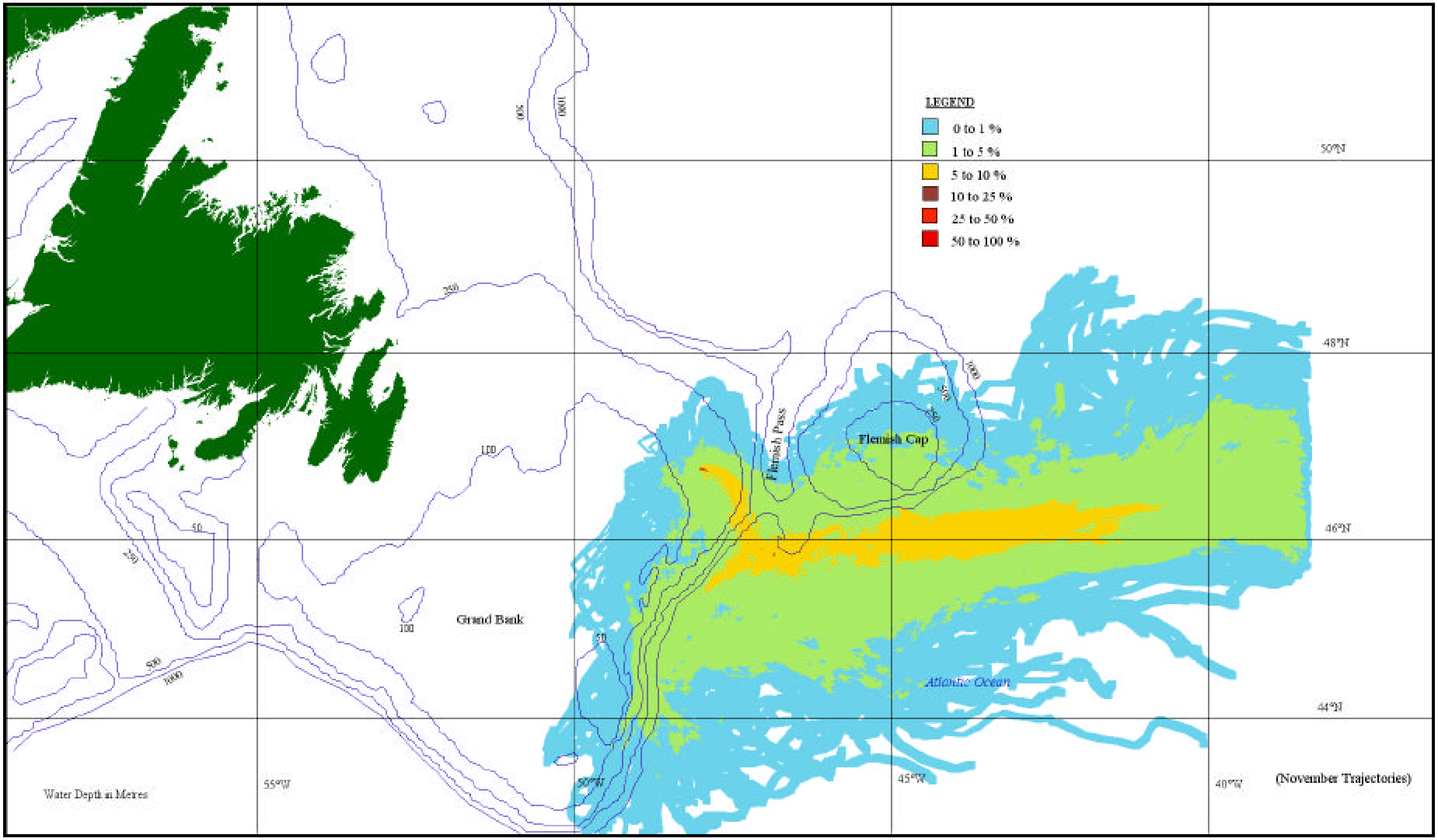
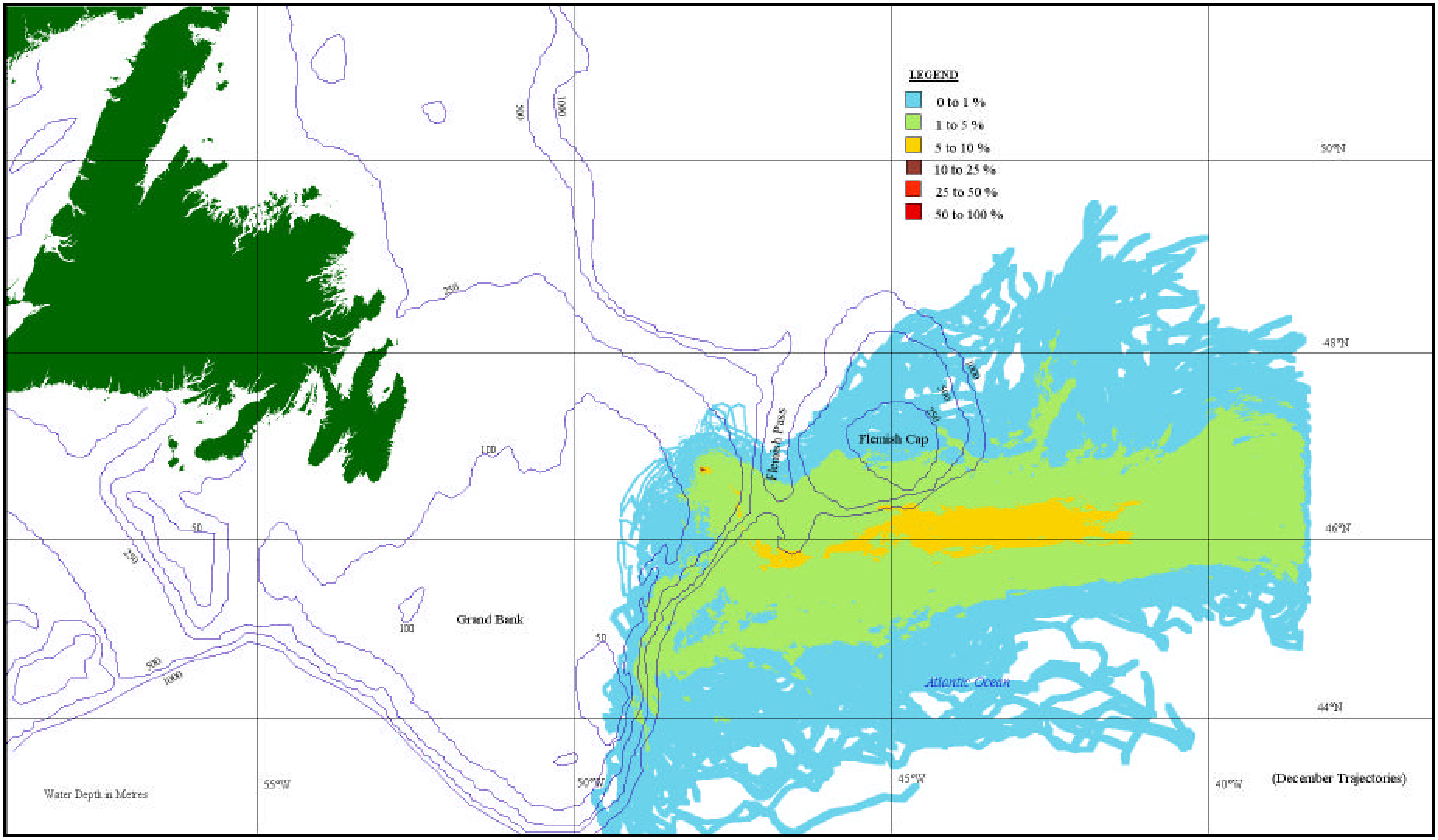


Figure 5.8–12 Probability That Oil Will Reach Any 1 x 1 km Block on the Grand Banks Based on Modelling of 1240 Spill Trajectories in December



It is important to note that these figures do not represent the distribution of oil from an individual oil spill. The figures are spill trajectory composites that show over 1,100 probable oil trajectories originating at the White Rose site for each month.

Small areas near the spill site have a high probability (50 to 100 percent) that oil from a potential spill will pass through them. This is represented by a bright red colour that is not visible on the figures at the scale shown. The bright orange colour, barely visible on the figures near the spill source, represents areas where 25 to 50 percent of the slicks pass. The dark brown colour, seen primarily in the summer and early fall months, shows areas where 10 to 25 percent slicks will likely pass. The yellow colour represents zones where 5 to 10 percent of the slicks are likely to pass. The green colour shows the area where 1 to 10 percent of the slicks pass. Less than one percent of the slicks pass through the light blue areas. Thus, these figures indicate the probability of oil reaching a selected point during any month of the year.

5.8.5.4 White Rose Spill Areas and Concentrations of Dispersed Oil

It was necessary to calculate estimates of the total areas potentially exposed to oil from accidental blowouts or spills at the White Rose site for effects assessment purposes.

The areas potentially influenced by oil released during the different scenarios are summarized in Table 5.8-14. The “thick oil area” basically remains unchanged throughout the 30-day modelling period because of the semi-solid nature of the oil. However, the thick oil will not be a continuous slick by the end of the 30-day period but rather, a large number of small mats, particles, and “wax” balls spread throughout the total slick area. The “total slick(let) area” represents the area influenced by both thick and sheen oil in the batch spills, or an individual slicklet from a blowout, at the end of the 30-day modelling period without considering movement of the oil by wind. The average slick(let) width is an average of the initial and 30-day total slick(let) widths.

Table 5.8-14 Areas Potentially Exposed to White Rose Oil from an Accidental Batch Spill or Blowout During Summer and Winter

Scenario	Season	Thick Oil Area (km^2)	Total Slick(let) Area (m^2)	Average Width of Slick(let) (km)	Total Oil Sweep Area (km^2)
800 m^3 Batch Spill	S	0.04	147	6.99	4,900
	W	0.04	75	5.10	4,760
10,000 m^3 Batch Spill	S	0.5	169	8.35	5,850
	W	0.5	90	6.45	6,000
30,000 m^3 Batch Spill	S	1.5	193	9.70	6,800
	W	1.5	110	7.90	7,400
7 day Subsea Blowout	S	0.21	3.8	1.86	36,500
	W	0.12	2.1	1.39	36,300
45 day Subsea Blowout	S	0.0052	2.7	1.38	174,000
	W	0.0029	1.4	1.02	171,000
7 day Surface Blowout	S	0.0037	2.5	0.90	17,640
	W	0.0056	0.45	0.41	10,500

The "oil sweep area" was used as the estimate for "geographic extent" in the effects assessment (see Section 5.9). It includes the total area that is "swept" by the average slick width over the 30-day modelling period and assumes that the seasonal average winds drive the movement of the slicks. The distance travelled by a slick was assumed to be 700 km in the summer and 933 km in the winter (3 percent of average wind speeds for summer 9 m/s and winter 12 m/s multiplied by the 30-day modelling period; Nerella and Jarvis 1980). For the blowout scenarios, it was assumed that a "unique" slick is generated every 6 h. For blowouts lasting seven days, areas of 28 slicks were combined to calculate a total sweep area. Similarly, for a 45-day blowout, a total of 180 slick areas were combined to calculate an estimate of the total surface area affected by the blowout.

As previously mentioned, the waxy nature of White Rose oil will limit dispersion of the oil in the water column. For effects assessment purposes, the maximum dispersed oil concentrations were predicted for the various batch spill and blowout scenarios (Table 5.8-15). It has been assumed that all dispersed oil accumulates and is homogenous in the 10 m directly below the slick to arrive at these concentration estimates. Concentrations of dispersed oil are low due to the high persistence of this oil on the surface that results from its tendency to form stable emulsions and its high pour point.

Table 5.8-15 Maximum Concentration of Dispersed White Rose Oil from an Accidental Batch Spill or Blowout During Summer and Winter

Scenario	Season	Max. Conc of Disp. Oil (ppm)
800 m^3 Batch Spill	S	0.0038
	W	0.00009
10,000 m^3 Batch Spill	S	0.0048
	W	0.00015
30,000 m^3 Batch Spill	S	0.0052
	W	0.00018
7 day Subsea Blowout	S	0.00013
	W	0.000001
45 day Subsea Blowout	S	0.00008
	W	0.000013
7 day Surface Blowout	S	0.0075
	W	0.0

5.8.6 Effects of Pack Ice on Oil Spills

The White Rose site lies close to the extreme southern limit of the regional pack ice (see Section 2.5.2.2, Spatial Distribution) for a detailed discussion of pack ice distribution. Pack ice incursions within 15 km of White Rose occur about half the data years (1960 to 1999), centered on mid-March, with durations varying from one to 11 weeks. Mean sea ice concentrations on the Grand Banks south of 49 degrees latitude are fairly consistent at 6/10ths coverage. Coverages greater that 5/10ths occur by early February and continue through mid-April, at which time they slowly decrease to 2/10ths (see Section 2.5.2.4, Concentrations).

Oil behaviour in pack ice and potential countermeasures have been studied extensively under the Environmental Studies Research Fund (ESRF) (Witherspoon et al. 1985; Abdelnour et al. 1986; SL Ross 1986; Brown and Goodman 1987; Comfort 1987; MacNeil and Goodman 1987; SL Ross and DF Dickins 1987).

The general movement of a large oil spill in pack ice will be similar to that of the ice. The specific behaviour of the White Rose crude in or near pack ice will be dependent upon the degree and type of ice coverage (R. Belore, pers. comm.). In general, high concentrations of brash ice will keep the oil from spreading and oil spilled outside heavy pack will not penetrate far into it (SL Ross and DF Dickins 1987). Oil spilled under the pack ice will probably tend to coat the underside of the ice. The waxy nature of the White Rose crude will not affect these general conclusions concerning the effects of pack ice on the spill (R. Belore, pers. comm.).

In the unlikely event of a major oil spill at White Rose, the potential for interaction with pack ice only occurs for a small period of the year (0 to 11 weeks). The main effect of the presence pack ice on oil spills will be to hinder the drilling of relief wells and/or cleanup efforts. On the other hand, certain pack ice conditions may serve to contain the oil and thus make it more likely to burn, assuming it could be ignited.

Effects of oil on under-ice algae have been studied by Cross (1987) during the experimental Baffin Island Oil Spill (BIOS). He concluded that crude and dispersed crude did not impact primary productivity after a 12-day exposure.

In conclusion, the presence of pack ice during an oil spill or blowout was considered to increase the likelihood of interaction between an accidental oil spill and young seals, and the effects are discussed in Section 5.9.2.3.

5.9 EFFECTS ASSESSMENT OF OFFSHORE OIL SPILL/BLOWOUT

5.9.1 Effects of Oil Spills and Blowouts on Valued Ecosystem Components – Existing Knowledge

This section reviews the known effects of spilled oil on the various biological components of the marine system. This information is then used, in conjunction with oil spill modelling data, to evaluate the potential effects of accidental events (spilled oil) at the White Rose site (Section 5.9.2).

5.9.1.1 Fish and Fish Habitat

The effects of oil spills on fish and fish habitat have been studied extensively. Comprehensive and recent reviews are contained in Armstrong et al. (1995) and Rice et al. (1996). The following sections highlight information relevant to assessing the effects of an offshore oil spill or blowout at White Rose. The reader is referred to Sections 5.1 to 5.7 for a discussion of oil spill probabilities and Section 5.8 for a discussion of the properties and behaviour of spilled White Rose crude oil. Effects on commercial fisheries are also discussed in the SEIS (Part Two).

Plankton

Plankton is not a VEC; however, fish habitat includes plankton because it is a source of food for larvae and some adult fish. Thus, effects of an oil spill or blowout on plankton could affect fish. Dispersion and dissolution cause the soluble, lower molecular weight hydrocarbons to move from the slick into the water column. Effects of spills on pelagic organisms need to be assessed through examination of effects of water-soluble fractions of oil or light hydrocarbon products.

Effects of crude oil spills on plankton are short-lived, with zooplankton being more sensitive than phytoplankton. Zooplankon accumulate hydrocarbons in their bodies. The hydrocarbons may be metabolized and depurated (Trudel 1985). Hydrocarbons accumulated in zooplankton during a spill would be depurated within a few days after a return to clean water and thus, there is limited potential for transfer of hydrocarbons up the food chain (Trudel 1985). There is a potential for transfer of hydrocarbons up the food chain in an environment subject to chronic inputs of hydrocarbons, but there is no potential for biomagnification.

Celewycz and Wertheimer (1996) concluded that the *Exxon Valdez* spill did not reduce the available prey resources, including zooplankton, of juvenile salmon in Prince William Sound. Studies of the fate of No. 5 fuel (diesel) spilled from the *Tsesis* (Johansson et al. 1980) showed that:

- primary production may be substantially inhibited by oil concentrations under a slick, even though standing crop and species composition of the phytoplankton may be unaffected;
- zooplankton standing crop can be drastically reduced in the immediate area of the spill; and
- a high proportion of the zooplankton may have oil adhered to their bodies and in their guts, indicating that they consume oil droplets.

Mortality of zooplankton can occur at diesel concentrations of 100 to 10,000 ppm (24 to 48 h LC_{50}, where LC_{50} is the concentration of toxicant that kills 50 percent of the test animals; Trudel 1985). Diesel oil is much more toxic than crude oil. There is great variability among species and some species are relatively insensitive. For example the 96-h LC_{50} of crude oil for *Calanus hyperboreus*, a common cold water copepod, is 73,000 ppm (Foy 1982). Complete narcotization of copepods can occur after a 15-min exposure to 1,800 ppm of aromatic heating oil and mortality can occur after a 6-h exposure (Berdugo et al. 1979).

Exposure to concentrations of 1,000 ppm of aromatic heating oil for 3-d had no apparent effect on mobility, but exposure for as little as 10 min shortened life span and total egg production (Berdugo et al. 1979). No. 2 fuel oil at concentrations of 250 to 1,000 ppm completely inhibited or modified copepod feeding behaviour, while concentrations of 70 ppm or lower may not affect feeding behaviour (Berman and Heinle 1980). Exposure to naphthalene at concentrations of 10 to 50 ppm for 10 days did not affect feeding behaviour or reproductive potential of copepods (Berdugo et al. 1979). The development of eggs was not examined.

In summary, individual zooplankton could be affected by a blowout or spill at White Rose through mortality, sublethal effects, or hydrocarbon accumulation if oil concentrations are high enough. However, as is indicated by Table 5.8-15, the predicted maximum concentrations for batch and blowouts is well below those known to cause effects.

Benthic Animals

Under some circumstances, oil spilled in nearshore waters can become incorporated into nearshore and intertidal sediments, where it can remain toxic and affect benthic animals for years after the spill

(Sanders et al. 1990). Oil from an offshore spill in deep water will not become incorporated in the sediments. Oil released from an offshore blowout will quickly rise to the surface. Drilling will occur in open water and because of the depths involved, there is little chance of oil adhering to suspended sediments and being deposited on the bottom. Thus, oil released during an offshore spill or blowout at White Rose will not interact with the benthos.

Fish Eggs and Larvae

Planktonic fish eggs and larvae (ichthyoplankton) are less resistant to effects of pollutants than are adults because they are not physiologically equipped to detoxify oil or to actively avoid it. Most eggs and larvae also develop at or near the surface where oil exposure is the greatest (Rice 1985; see also Section 3.6 for a detailed description of ichthyoplankton on the Grand Banks). It is estimated that sensitivities of fish larvae range from 0.1 to 1.0 ppm of soluble aromatic hydrocarbons, which are approximately 10 times more sensitive than those of adults (Moore and Dwyer 1974). However, an organism's sensitivity to oiling is not simply a function of age.

Fish eggs may be highly sensitive at certain stages and become less sensitive prior to hatching (Kühnhold 1978; Rice 1985), while larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to oil generally exhibit morphological malformations, genetic damage, and reduced growth. Quite often damage to an embryo is not apparent until the egg hatches. For example, although Atlantic cod eggs survived oiling, the larvae were deformed and could not swim (Kühnhold 1974). Atlantic herring larvae exposed to oil showed behavioural abnormalities: increased swimming activity followed by low activity, narcosis, and eventually death (Kühnhold 1972). Similarly, Pacific herring (*Clupea pallasi*) eggs and larvae (possibly exposed as embryos) collected from beaches contaminated with *Exxon Valdez* oil in 1989 exhibited morphological and genetic damage (Hose et al. 1996; Norcross et al. 1996; Marty et al. 1997). Marty et al. (1997) indicated that herring larvae collected from oiled sites had ingested less food, displayed slower growth, and had a higher prevalence of cytogenetic damage than those sampled from unoiled sites. However, these effects were not observed in eggs and larvae collected in later years (Hose et al. 1996; Norcross et al. 1996) and no conclusive evidence exists to suggest that these oiled sites posed a long-term hazard to fish embryo or larval survival (Kocan et al. 1996).

The effects of oil exposure on local population levels and community structure of fish are not well known. The natural mortality rate, in fish eggs and larvae, in the absence of oil is very high; large numbers could be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985). Oil-related mortalities would probably not affect year-class strength unless >50 percent of the larvae in a large proportion of the spawning area died (Rice 1985). Herring are one of the most sensitive fish species to oiling. Hose et al. (1996) claim that even though 58 percent fewer herring larvae were produced at a site oiled during the *Exxon Valdez* spill than expected if oiling had not occurred, no effect would be detected at the population level.

Ten day exposure of large numbers of pink salmon smolt (*Oncorhynchus gorbuscha*) to the water-soluble fraction of crude oil (0.025 to 0.349 ppm) and their subsequent release to the Pacific Ocean did not result in a detectable effect on their survival to maturity compared to non-exposed fish (Birtwell et al. 1999). However, it should be noted that pink salmon may be more resistant to environmental disturbance than other species because pink salmon spend more time in the variable estuarine environment.

About 45 species of ichthyoplankton may occur in the White Rose area. Their occurrence, abundance and distribution are highly variable depending upon season and a variety of biological (e.g., stock size, spawning success, etc.) and environmental conditions (temperature, currents, etc.). In the unlikely event of a blowout or spill at White Rose, there is potential for individual ichthyoplankton occurring in the upper water column to sustain lethal and sublethal effects if they come in contact with high concentrations of oil. The LC_{50} value at 25°C used by Hurlbut et al. (1991) was 0.0143 ppm.

Invertebrate Eggs and Larvae

As in the case of fish larvae, the sensitivity of invertebrate larvae to petroleum hydrocarbons varies with species, life history stage, and type of oil. Generally, larvae are more sensitive to effects of oil than are adults.

Sublethal and lethal effects on individual larvae are possible during a spill or blowout at White Rose.

American lobster larvae (Stages 1 to 4) showed a 24-h LC_{50} of 0.1 ppm to Venezuelan crude oil (Wells 1972). Larvae exposed to 0.1 ppm of South Louisiana crude oil swam and fed actively while those exposed to 1 ppm were lethargic (Forns 1977). Crab Stage 1 larvae (king crab, *Paralithodes camtschatica* and Tanner crab (*Chionectes bairdi*)) succumbed to similar concentrations of crude oil (0.96 to 2 ppm; Brodersen et al. 1977) while larval shrimp generally had higher LC_{50} limits (0.95 to 7.9 ppm; Brodersen et al. 1977; Mecklenburg et al. 1977). Anderson et al. (1974) tested a variety of crude and refined oils and found that post-larval brown shrimp (*Penaeus aztecus*) were less sensitive than adult invertebrate species. Also, moulting larvae are generally more sensitive to oil than intermoult larvae (Mecklenburg et al. 1977). Kerosene affected development of sea urchin embryos at concentrations of 15 ppb or greater and gasoline did so at concentrations of 28 ppb or greater (Falk-Petersen 1979).

Invertebrate larvae exposed to oil may exhibit reductions in food consumption and growth rate, while oxygen consumption increases (Johns and Pechenik 1980). Despite these physiological changes, deleterious effects on invertebrate populations have not been detected even after major oil spills (Armstrong et al. 1995). Larval distribution, settlement, fecundity, recruitment and growth of juveniles and subadult crab, pandalid shrimp, clams and scallops were not significantly affected by the *Exxon Valdez* oil spill (Armstrong et al. 1995).

Adult Fish

The potential effects of an oil blowout or spill on fish is dependent on timing and location. The most sensitive stages for all fish species are the egg and larval stages (discussed above). Most adult fish can and probably will avoid high concentrations of oil (Irwin et al. 1997). Possible exceptions are situations where hydrocarbons have become incorporated into sediments and the species is highly associated with those sediments. An example would be an oil spill in a very shallow, sand-pebble, low energy environment, where young flounder may prefer to bury themselves in the sediment. This would not be the situation at White Rose. As was previously indicated, it is very unlikely that oil from a spill at White Rose would be incorporated into the sediment.

Oil can cause lethal or sublethal effects on fish. Fish may die directly through coating of the gills with oil, which hinders gas exchange and results in suffocation. Mortality may also occur from toxic effects, where components of the oil disrupt physiological processes. Sublethal and long-term effects may include disruption of physiological and behavioural mechanisms, reduced tolerance to stress, and incorporation of carcinogens into the food chain. These physiological and behavioural effects are discussed in the following sections.

Physiological Effects

The sensitivity of fish to oil exposure varies by phylogenetic group and habitat use. Pelagic fish tend to be the most sensitive (LC_{50}s of 1 to 3 ppm), benthic species are moderately tolerant (LC_{50}s of 3 to 8 ppm), and intertidal fish are usually the most tolerant (LC_{50}s of >8 ppm) (Rice et al. 1979).

Fish are exposed to oil by ingestion of contaminated seawater or prey and through their gills. Direct exposure of fishes to oil alters cell membrane structure and function (Sanders et al. 1981 in Brzorad and Burger 1994) that can lead to abnormal gill function (Engelhardt et al. 1981 in Brzorad and Burger 1994) and other physiological problems. This may result in death due to hemorrhaged gills, brain and liver (e.g., Fink and Duval 1980).

When exposure levels of oil are not lethal, many fish species detoxify harmful compounds of oil. The liver enzyme systems (microsomal mixed-function oxidases or MFO) become more active when exposed to oil. The MFO system depurates contaminants by facilitating their bio-transformation. Contaminants are metabolized into a metabolite that is more water-soluble so that they can be excreted easily (Koning 1987). MFO systems require additional energy to operate. Consequently, fish exposed to oil grow slower, probably as a result of lower feeding rates or elevated metabolic rates (Schwartz 1985 in Brzorad and Burger 1994).

Fish can also excrete oil (lower weight aromatic hydrocarbons like toluene and naphthalene; Thomas and Rice 1981; 1982) through their gills and in mucous secretions of the skin (Varanasi et al. 1978). Hydrocarbons and their metabolites that are not excreted can concentrate in fish tissue. This may lead to damage of the liver, gut, pancreas, vertebrae, stomach, brain and olfactory organs (Rice 1985:166), and physiological changes in heart rate, respiration, blood parameters and ion concentrations (Rice 1985: 167). Disruption of the outer layer of fishes, which acts as the first line of defense against pathogens, increases the occurrence of disease (Brown et al. 1973; Steedman 1991 in Brzorad and Burger 1994). These effects may eventually result in death or limited growth and decreased reproductive success. Mortality of oiled adults generally occurs in confined areas like bays and estuaries where oil is less likely to disperse.

Carls et al. (1998) presented evidence indicating that activation of viral hemorrhagic septicemia virus (VHSV) may occur in Pacific herring exposed to crude oil after a spill. Marty et al. (1999) concluded that Pacific herring exposed to *Exxon Valdez* oil in 1989 developed hepatic necrosis, probably as a result of VHSV.

Juveniles of various flatfish species showed reduced growth following 30 to 90 days of exposure to sediments laden with Alaska North Slope crude oil. After 90 days, there were also changes in fish health. Indicators included increased fin erosion, liver lipidosis, gill hyperplasia and incidence of gill parasites. These were coupled with decreases in macrophage aggregates and reduced growth (34 to 56 percent) at hydrocarbon concentrations of 1,600 μg/g sediment (Moles and Norcross 1998).

Most sublethal effects of oil observed in laboratory studies of fish were caused at concentrations of oil that ranged from 0.1 to 1.0 ppm. These concentrations are rarely reached in water contaminated by an accidental oil release, especially oil from a blowout. For example, concentrations of oil under a slick are generally less than 0.1 ppm (Gordon et al. 1976; Mackay et al. 1982).

Stress caused by fluctuations in temperature, salinity, food abundance, disease, and parasites may reduce the ability of fish to tolerate oil (Rice 1985). For example, starry flounder (*Platichthys stellatus*) retained more naphthalene when exposed at low temperatures than when exposed at high temperatures (Varanasi et al. 1981 in Rice 1985). The life history stage of a fish may also influence its sensitivity to hydrocarbons. For instance, spawning herring are very sensitive to oil and are unable to metabolize it (Rice et al. 1987). Oil concentrates in the lipid rich ova (Rice et al. 1987) where it affects eggs (Struhsaker 1977) and newly hatched larvae.

Behavioural Effects

Fish are capable of detecting and avoiding oil-contaminated waters but short-term exposures could damage the sensitive olfactory epithelia used to detect pollutants (Rice 1985). Even if fish detect oil, they may or may not avoid it. Conflicting reports of fish mortality in the field exist (see Rice 1985:170). Fish may be highly motivated to migrate to a certain area even though they may have to pass through an oiled area. There are limited controlled field studies addressing this issue. One such study tested whether adult salmon returning to a home stream avoided a contaminated fish ladder and used an uncontaminated ladder instead. Salmon did avoid the contaminated ladder when concentrations of monoaromatic hydrocarbons approached acutely toxic levels (Weber et al. 1981). In a laboratory study, cod avoided refined petroleum products in water at concentrations >100 μg/L. Below this level, most fish were indifferent and above it, more fish avoided the oil (Bohle 1986 in Crucil 1989).

Oil may also indirectly affect fish by altering schooling, predator avoidance and foraging behaviour. Atlantic silversides (*Menidia menidia*) lose their ability to school after oiling, presumably because of damage to their olfactory and lateral line organs (Gardner 1975). Sand lance normally avoid heavy predation from seabirds and fish by burying in the sand when not foraging and during overwintering. Oil contamination of sand led to a 20 percent decrease in the time these fish spent buried (Pearson et al. 1984). This may result in an increased mortality rate caused by increased predation. Sexually mature Arctic cod (*Boreogadus saida*) consumed both contaminated and uncontaminated food. However, food contaminated with oil at a concentration of 500 ppm was rejected. The ingestion of oil-contaminated food led to a depression in growth (Christiansen and George 1995).

Fisheries

Although fish kills have been reported after oil spills and blowouts, a decrease in fishery stocks has never been attributed to these events (Rice 1985; Armstrong et al. 1995). Oil spills and blowouts have probably caused more economic harm because consumers are reluctant to buy fish that have the potential to be tainted.

The technical term ‘tainting’ was introduced to designate gustatory and/or olfactory impairment of foods. In 1982, the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) defined tainting in marine organisms as “a foreign flavour or odour in the organisms induced by conditions in the water to which the organisms are exposed”. Off-taste is considered as a warning sign, indicating an onset of enzymatic degradation and bacteria-associated spoilage, especially with regard to fish (Höfer 1998a; 1998b).

Fish become tainted when oil is taken up into tissues (usually lipid-rich tissues). Tainting imparts an oily taste to the fish and makes them unpalatable and of no commercial value. Experienced taste testers can detect 10 to 30 ppm crude oil in cooked or raw fillets (Corner et al. 1976). The type of hydrocarbon and the lipid content of the fish species are the two main factors affecting the acquisition of taint (Tidmarsh et al. 1986). Principal components of oil that cause taint include phenols, dibenzothiophenes, naphthenic acids, mercaptans, tetradecanes, and methylated naphthalenes. These compounds are water- and lipid-soluble, so they are readily taken in and transferred into the tissues of fish. Fish such as herring and capelin, which are high in fat, are more susceptible to taint than species like cod and haddock that have lower fat content (Sidwell 1981). Shellfish have a relatively low lipid content, ranging from 0.2 percent in scallops to 2.0 percent in oysters and crab (Ackman 1976). The susceptibility of fish to tainting may also vary seasonally. Fish like plaice and cod are more susceptible to tainting in the spring, possibly as a result of low MFO activity and decreased metabolic rate (Robson et al. 1987).

Although chemical tainting has been observed, there have been only a few systematic studies of its occurrence and its causes. Tainting has occurred mostly in extremely polluted waters and subsequent to coastal tanker accidents. For example, fish farming was impaired for two years in the Braer accident area (Scotland), although relatively few fish near the accident site were even slightly chemically contaminated (Höfer 1998b). There are no reports suggesting an impairment of the flavour of marine fish as a result of tank cleaning or oil discharge at high sea. Increased levels of hydrocarbons were found in fish from production platform sites in the North Sea, but these levels were not associated with any impairment of flavour (Parker et al. 1990).

Even if no tainting actually occurs, the fear of tainting can negatively influence the economic stability of fisheries. Areas around oil spills and blowouts have been closed without any evidence that tainting has occurred or is likely to occur. For example, a no fishing zone was imposed around the Uniacke wellsite near Sable Island during the blowout of 1984. Taste tests conducted on cod, halibut and haddock caught in the immediate vicinity of the well site did not indicate tainting had occurred (Zitko et al. 1984). Similarly, inspection officers rejected lobsters with any trace of external oiling and no proof of internal contamination during the *Kurdistan* oil spill (Tidmarsh et al. 1986). In an extreme instance, shellfish prices and sales declined dramatically after the Torrey Canyon spill, even though much of the shellfish catch was from other waters. In Canada, U.S. and U.K., areas around oil spills are closed to fishing as a matter of policy until it can be demonstrated that there are no contamination effects. This is done to protect against declines in marketability and prices.

Tests with Hibernia crude (water soluble fraction (WSF)) have shown that a concentration of approximately 0.5 ppm will impart a taint to cod after a 24-h exposure and that concentrations of less than 0.2 ppm will taint cod after an exposure of three days (Ernst et al. 1987). Flatfish near blowout or spill sites may become tainted if hydrocarbon concentrations in sediments exceed 200 ppm dry weight (S.L. Ross and LFA 1993). Although it has been shown that flatfish can bioaccumulate hydrocarbons in their livers from drill cuttings, it is unclear whether flatfish accumulate enough hydrocarbons in their tissue to cause tainting (S.L. Ross and LFA 1993). It is very unlikely that a fish would be subjected to oil concentrations of sufficient magnitude to cause tainting from a blowout within the study area. The duration of exposure to concentrations required to cause tainting would occur only under extreme circumstances.

Comparative studies with different fish and crustacean species are not available in the numbers required for an extrapolation of laboratory results to the natural environment. Although the risk of an impairment of flavour could be established, estimation of the risk involved after ship accidents must consider additional factors, including total mass of pollutant spilled, dilution, water movement, resultant exposure period for the biota, physico-chemical properties of the substances involved and season. All of these factors help determine the environmental behaviour (such as, vaporization, sedimentation) of the spilled substance (Höfer 1998a).

Effects predictions for an accidental event associated with the White Rose oilfield development on fish and fish habitat are detailed in Section 5.9.2.1. The potential effects of an oil spill on fisheries are discussed in Part Two of the Comprehensive Study.

5.9.1.2 Marine Birds

It is an accepted fact that birds are the group most at risk from marine oil spills and blowouts and that the Grand Banks is a very important area for large numbers of seabirds (Section 3.9). Exposure to oil causes thermal and buoyancy deficiencies in birds that usually lead to death. Although some birds may survive these immediate effects, long-term physiological changes may eventually result in death (Ainley et al. 1981; Williams 1985; Frink and White 1990; Fry 1990). Reported effects vary with the species of bird, type of oil (Gorsline et al. 1981), weather, time of year, and duration of the spill or blowout. Oil spills at sea can kill tens of thousands of birds (Clark 1984; Piatt et al. 1990); however, recent studies suggest that even spills of great magnitude, may not have significant long-term effects on seabird populations (Clark 1984; Wiens 1995).

Immediate Effects

External exposure to oil occurs when a flying bird lands in an oil slick, or when a diving bird surfaces from underneath an oil slick or when a swimming bird swims into a slick. This results in the matting of feathers, which effectively destroys the thermal insulation and buoyancy provided by the air trapped by the feathers. Consequently, oiled birds are likely to suffer from hypothermia or drown (Clark 1984; Hartung 1995). Most bird losses occur during the initial phase of an oil spill when large numbers of birds are exposed to floating oil (Hartung 1995). Birds living in cold water environments, like those found in the study area, are more likely to succumb to hypothermia (Hartung 1995).

Short-term Effects

Oiled birds that escape death from hypothermia or drowning often seek refuge ashore, where they engage in abnormally excessive preening in an attempt to rid themselves of oil (Hunt 1957 in Hartung 1995). This leads to the ingestion of significant quantities of oil which, although apparently only partially absorbed (McEwan and Whitehead 1980), can have lethal effects. Noted effects in murres (common and thick-billed) oiled off Newfoundland’s south coast include emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance (Khan and Ryan 1991). Glaucous-winged gulls (*Larus glaucescens*) experienced similar effects after they ingested bunker fuel oil during preening (Hughes et al. 1990). Another common effect observed is adrenal hypertrophy that renders birds more vulnerable to adrenocortical exhaustion (mallards: Hartung and Hunt 1966; Holmes et al. 1979; black guillemots: Peakall et al. 1980; herring gulls: Peakall et al. 1982). The adrenal gland maintains water and electrolyte balance that is essential for the survival of birds living in a marine environment. Hartung and Hunt (1966) found that ingested oils caused lipid pneumonia, gastrointestinal irritation, and fatty livers in several species of ducks. Aromatic hydrocarbons have been detected in the brains of mallards (Lawler et al. 1978) and are probably associated with observed symptoms (lack of coordination, ataxia, tremors and constricted pupils) of nervous disorders (Hartung and Hunt 1966).

Birds exposed to oil are at risk of starvation (Hartung 1995). For example, oiled common eiders generally deplete all of their fat reserves and much of their muscle protein (Gorman and Milne 1970). In addition, energy demands are higher (which expedites starvation) because the metabolic rate of oiled birds increases to compensate for the heat loss caused by the reduced insulating capacity of their plumage (Hartung 1967; McEwan and Koelink 1973).

Long-term Effects

It appears that direct, long-term sublethal toxic effects on birds are unlikely (Hartung 1995). The extent of bioaccumulation of the components of oil in birds is limited because vertebrate species are capable of metabolizing the components at rates that prevent bioaccumulation (Neff 1985 in Hartung 1995). Birds generally excrete much of the hydrocarbons within a short time period (McEwan and Whitehead 1980). However, nesting seabirds that are contaminated with oil, and survive, generally exhibit decreased reproductive success.

Nesting seabirds transfer oil from their plumage and feet to their eggs (Albers and Szaro 1978). Very small quantities of oil, ranging from 1 to 20 microlitres (1-20 millionths of a litre), on eggs have produced developmental defects and mortality in avian embryos from many species (Albers 1977; Albers and Szaro 1978; Hoffmann 1978, 1979a; Macko and King 1980; Parnell et al. 1984; Harfenist et al. 1990). The resulting hatching and fledging success of young is related to the type of oil (Hoffman 1979b; Albers and Gay 1982; Stubblefield et al. 1995) and time of exposure during incubation. Embryos are most sensitive to oil during the first half of incubation (Albers 1978; Leighton et al. 1995). Breeding birds that ingest oil generally exhibit a decrease in fertilization (Holmes et al. 1978), egg laying and hatching (Hartung 1965; Ainley et al. 1981), chick growth (Szaro et al. 1978) and survival (Vangilder and Peterle 1980; Trivelpiece et al. 1984). Similar effects on ducklings occur when they ingest oil directly (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981). Oil spills can also cause indirect reproductive failure. Eppley and Rubega (1990) suggest that exposure to an Antarctic oil spill caused changes in the normal parental behaviour of south polar skuas (*Catharacta maccormicki)*, which exposed young to increased predation and contributed to reproductive failure in that population. In another case, abandonment of nesting burrows by oiled adult Leach's storm-petrels may have contributed to reproductive failure in that population (Butler et al. 1988). Thus, a spill that occurred during the reproductive period could cause mortality of young, even if the adults survived exposure to oil.

There is no conclusive evidence that oil spills have caused marked reductions in bird populations or have changed community structure at a large scale (Leighton 1995). Some studies have suggested that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics

(Clark 1984; Butler et al. 1988; Boersma et al. 1995; Wiens 1995) while others suggest the opposite (Piatt et al. 1990; Walton et al. 1997). Natural interannual variation in factors like prey availability and weather, which influence population dynamics, reduce the ability of scientists to assess the effect of oil spills on bird populations.

Species Most at Risk

It is clear from investigations of oil spills that truly aquatic and marine species of birds are most vulnerable and most often affected by marine oil spills. Diving species such as guillemots, murres, puffins, dovekies, eiders, oldsquaws, scoters, mergansers, and loons are considered to be the most susceptible to the immediate effects of surface slicks (Leighton et al. 1985; Chardine 1995; Wiese and Ryan 1999). Alcids had the highest oiling rate of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland and were the only group of seabirds to show an annual increase over a 13-yr period (2.7 percent) in the proportion of oiled birds (Wiese and Ryan 1999). Within this group, murres appear to be the most affected by exposure to oil. Also, there was a strong seasonal effect as significantly higher proportions of alcids (along with other seabird groups) were oiled in winter versus summer (Wiese and Ryan 1999).

Other species such as northern fulmar, shearwaters, storm-petrels, gulls (including kittiwakes), and terns can be vulnerable to contact with oil because individuals feed over wide areas with frequent contact with the water's surface. They also are vulnerable to the disturbance and habitat damage attendant on cleaning up spilled oil (Lock et al. 1994). The greatest decrease in use of contaminated habitats immediately after a spill occurs in species that feed on or close to shore, and that either breed along the coast or are full-year residents (Wiens et al. 1996). In the study area, this would include species like terns and storm-petrels. Oil residues in bedrock habitat, like that used by most seabirds in Newfoundland, do not remain as long as residues in sedimentary habitat (for example, sand beaches) (Gilfillan et al. 1995).

Birds are particularly vulnerable to oil spills during nesting, moult, and before young seabirds are able to fly. Newly fledged murres and gannets are unable to fly for the first two to three weeks they are at sea, and are therefore less likely to avoid contact with oil during this time (Lock et al. 1994). Before and during moult, the risks of hypothermia and drowning (Erasmus and Wessels 1985) are increased because feather wear and loss reduce the water repellency by about half (Stephenson 1997). Section 3.9.4 provides a further discussion on particularly vulnerable areas and species found within the study area.

Past Oil Spills In and Near the Study Area

Several major oil spills have occurred within and near the study area, and "small" oil releases (most likely from bilge pumping and deballasting by vessel traffic through the nearby shipping lanes) occur frequently. "Mystery" spills, most likely from ships that illegally dump waste oils into the ocean, killed an estimated 18,000 seabirds in Placentia Bay, Newfoundland (Anon. 1990). Many ships frequent the waters off the south coast of Newfoundland as they traverse between Europe and North America, thereby exposing seabirds to chronic levels of oil pollution (Chardine and Pelly 1994). In February 1970, the *Irving Whale* spilled between 3,000 and 7,000 gallons of Bunker C oil near St. Pierre and Miquelon, which subsequently spread along Newfoundland's southeast coast. It was estimated that 7,000 birds, primarily common eiders, were killed (Brown et al. 1973). During the same month, the *Arrow* ran aground in Chedabucto Bay, Nova Scotia. Approximately 2.5 million gallons of Bunker C fuel oil were spilled and at least 2,300 birds were killed in the bay itself (Brown et al. 1973). Diving birds were mainly affected, most notably oldsquaws, red-breasted mergansers, murres, dovekies, and grebes (Brown et al. 1973).

The spill spread offshore to Sable Island where mostly murres, dovekies, and fulmars were killed; the lowest estimate of mortality of this part of the slick was estimated at 4,800 birds (Brown et al. 1973).

On a broader geographical scale, it is estimated that 21,000 birds die annually from operational spills on the Atlantic coast of Canada and that 72,000 birds die annually from all operational spills in Canada (Thomson et al. 1991). Clark (1984) estimates that 150,000 to 450,000 birds die annually in the North Sea and North Atlantic from oil pollution of all sources. There is no clear correlation between the size of an oil spill and numbers of seabirds killed (Burger 1993). The density of birds in a spill area, wind velocity and direction, wave action, and distance to shore may have a greater bearing on mortality than size of the spill (Burger 1993).

Accordingly, even small spills can cause cumulative mass mortality of seabirds (Joensen 1972). A major spill that persisted for several days near a nesting colony could kill a high proportion of the pursuit-diving birds (for example, murres) within the colony (Cairns and Elliot 1987). In contrast, relatively low mortalities have been recorded from some huge spills. For example, the *Amoco Cadiz* spilled 230,000 tonnes of crude oil and caused the recorded deaths of 4,572 birds along the French coast (Clark 1984).

Rehabilitation

The rescue, cleaning, and rehabilitation of oiled birds has been practised in several parts of the world for a number of years (Clark 1984). Considerable effort has been made to improve rehabilitation techniques (Berkner et al. 1977; Williams 1985; Frink and White 1990) and release rates of birds have generally increased (Randall et al. 1980; Williams 1985; Frink 1987). However, success of rehabilitation cannot be measured in terms of number of birds released from treatment centres because cleaned seabirds often die shortly after release (Sharp 1996). Oiled and cleaned guillemots, white-winged scoters, and western grebes (*Aechmophorus occidentalis)* in North America had a much lower survival rate than non-oiled controls regardless of cleaning techniques (Sharp 1996). Similarly, Swennen (1977 in Sharp 1996) found that oiled, cleaned birds "released" into large enclosures had an annual mortality rate of 35 to 37 percent compared with a mortality rate of 7 percent for non-oiled controls. Radio-tagged brown pelicans

(*Pelecanus occidentalis*) that had been oiled and cleaned also had a much lower survival rate than non-oiled birds (D. Anderson, pers. comm. in Sharp 1996).

Bird rescue, cleaning, and treatment are not only ineffective but also are very costly (Cross et al. 1990; Sharp 1996). For instance, after the *Exxon Valdez* spill approximately U.S. $41 million (Sharp 1996) was spent on the collection of 36,000 birds and the rehabilitation of 1,630 birds rescued alive (J. Holcomb, IBRRC, pers. comm). Only 800 birds were released and most of these likely died within a short period of time (Sharp 1996). Piatt et al. (1990) estimated that 100,000 to 300,000 birds were killed by oil from the *Exxon Valdez*. Therefore, the massive rescue attempts associated with the *Exxon Valdez* spill managed to release (not save) only 0.3 to 0.8 percent of the birds that were potentially fatally oiled by the spill. Some groups like the Royal Society for the Prevention of Cruelty to Animals and the Royal Society for the Protection of Birds have recognized the failures of rehabilitation and have adopted an official policy that oiled birds should be humanely destroyed (Clark 1984). It has been suggested that oil spill rehabilitation funds should be redirected to the prevention of damage, rather than focussing on ineffective attempts at rehabilitation after the damage has occurred (Sharp 1996; Estes 1998).

Efforts to recover and rehabilitate oiled seabirds from an offshore spill or blowout associated with a drilling site at White Rose would be severely restricted by logistical problems and safety concerns (distance offshore, safety of personnel recovering birds, limited initial treatment facilities offshore). Consequently, the chances for a successful recovery effort are even less than in the case of the *Exxon Valdez.*

Enhancement Techniques

In the unlikely event that seabird populations are significantly affected by oil spills (Clark 1984; Wiens 1995), it may be possible to restock populations. Although no efforts to restock birds in areas that have suffered from major oil spills have been conducted, there have been several programs to reintroduce birds into abandoned parts of their ranges. Approaches have included releasing captive-reared fledgling birds at natural or artificial nest sites (for example, hacking of peregrine falcons); placing eggs from nests in one part of the range (or from captive birds) into nests of similar species in the areas of concern (for example, peregrine eggs into prairie falcon nests, whooping crane eggs into sandhill crane nests, trumpeter swan eggs into mute swan nests); and releasing juvenile and adult birds into selected receiving areas (for example, Atlantic puffins off the Maine coast and along the Brittany coast, and Canada geese in many areas).

These efforts have met with variable success. They all involve much planning and the programs are multi-year efforts that require a long-term commitment of personnel and resources. The case most relevant to the study area involves the successful reestablishment of colonies of Atlantic puffins in New England and France (Duncombe and Reille 1980; Clark 1984). Puffins are alcids and are close relatives of the murres and black guillemots that, along with the puffin, nest abundantly in southern Newfoundland. However, the puffins nest in burrows, whereas murres are cliff-nesters and guillemots nest among rocks and coastal debris. Consequently, it is unclear whether the techniques used in the successful reestablishment of nesting puffins would also work with these other alcids.

The nesting success of some species can be improved by manipulation of nesting habitat. For example, in Alaska, common eider females nest preferentially in well-protected areas near logs and among driftwood and rocks (Johnson and Herter 1989). Thus, the numbers of nesting sites could be increased by adding and rearranging driftwood along coasts and on offshore islands (S.R. Johnson, pers. comm.). Similar manipulations of eider nesting habitat are already underway in Atlantic Canada to improve nesting success. Also, in Iceland, the nesting habitat of eiders is manipulated to improve nesting success and to facilitate the collection of the eider down that lines the nests.

One option for enhancing recovery of depleted species is to eliminate hunting of that species, if it is a hunted species. Depending upon the severity of the situation, hunting could be curtailed locally in and near the study area, or on a wider basis.

The techniques to rescue and rehabilitate oiled birds are not very effective. Consequently, the best mitigation technique is to do all that is possible to avoid an oil spill in the first place. Otherwise, deploy countermeasures that reduce the numbers of birds that become oiled, for example, by directing the oil away from seabird concentration areas. It is much better to direct efforts to techniques that prevent birds from becoming oiled in the first place. Successful and efficient techniques are not yet available to restore bird populations and habitat once they are oiled. Effects predictions for an accidental event associated with the White Rose oilfield development on marine birds are detailed in Section 5.9.2.2.

5.9.1.3 Marine Mammals

With the exception of fur seals, polar bears, and sea otters, most marine mammals are not very susceptible to deleterious effects of oil. However, newborn hair seal pups, and weak or highly stressed individuals, may be vulnerable to oiling. Other marine mammals exposed to oil are generally not at risk because they rely on a layer of blubber for insulation and oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman et al. 1976; 1977; Geraci 1990; St. Aubin 1990). Population-level effects are unlikely, as no significant long-term and lethal effects from external exposure, ingestion, or bioaccumulation of oil have been demonstrated.

Cetaceans

There is no clearcut evidence that implicates oil spills, including the much studied *Santa Barbara* and *Exxon Valdez* spills, with the death of cetaceans (Geraci 1990). Migrating gray whales were apparently not adversely affected by the *Santa Barbara* spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill was a result of increased survey effort related to the spill (Geraci 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci 1990).

There was a significant decrease in the size of a killer whale pod resident in the area of the *Exxon Valdez* spill, but no clear cause and effect relationship between the spill and the decline could be established (Dahlheim and Matkin 1994). There were no evident effects on humpback whales in Prince William Sound after the *Exxon Valdez* spill (von Ziegesar et al. 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but oil contamination, boat and aircraft disturbance, or displacement of food sources could have caused this displacement.

Avoidance and Behavioural Effects

Studies of both captive and wild cetaceans indicate that they can detect oil spills. Captive bottlenose dolphins (*Tursiops truncatus*) avoided most oil conditions during daylight and darkness, but had difficulty detecting a thin sheen of oil (St. Aubin et al. 1985). Wild bottlenose dolphins exposed to the *Mega Borg* oil spill in 1990 appeared to detect, but did not consistently avoid contact with, most oil types (Smultea and Würsig 1995). This is consistent with other cetaceans behaving normally in the presence of oil (Harvey and Dahlheim 1994; Matkin et al. 1994). It is possible that cetaceans swim through oil because of an overriding behavioural motivation (for example, feeding). Some evidence exists that indicates dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995).

Oiling of External Surfaces

Whales rely on a layer of blubber for insulation and oil has little if any effect on thermoregulation. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci 1990). It can be assumed that if oil contacted the eyes, effects would be similar to that observed in ringed seals (conjunctivitis, corneal abrasion, and swollen nictitating membranes) and that continued exposure to eyes could cause permanent damage (St. Aubin 1990).

Ingestion and Inhalation of Oil

Whales could ingest oil with water, contaminated food, or oil could be absorbed through the respiratory tract. Species like the humpback whale, right whale, beluga (*Delphinapterus leucas*), and harbour porpoise that feed in restricted areas (for example, bays) may be at greater risk of ingesting oil (Würsig 1990). Some of the ingested oil is voided in vomit or feces but some is absorbed and could cause toxic effects (Geraci 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982). Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982). Only small traces of oil were found in the blubber of a gray whale and liver of a killer whale exposed to *Exxon Valdez* oil (Bence and Burns 1995).

Cetaceans may inhale vapours from volatile fractions of oil from a spill and blowout. The most likely effects of inhalation of these vapours would be irritation of respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Stressed individuals that could not escape a contaminated area would be most at risk.

Fouling of Baleen

In baleen whales, crude oil could coat the baleen and reduce filtration efficiency. However, effects are minimal and reversible. Baleen experimentally fouled with oil did not change enough to alter its filtration efficiency (St. Aubin et al. 1984) and most adherent oil was removed within 30 min after fouling (Geraci and St. Aubin 1985 in Geraci 1990). The effects of oiling of baleen on feeding efficiency appear to be only minor (Geraci 1990).

Seals

Reports of the effects of oil spills and blowouts have shown that some mortality of hair seals may have occurred as a result of oil fouling; however, large scale mortality has never been observed (St. Aubin 1990). The largest effect of a spill was on young hair seals in cold water (St. Aubin 1990).

Effects on seals have not been well studied at most spills because of lack of baseline data and/or the brevity of the post-spill surveys. There is little information about the mortality rate of harp seals exposed to oil from a ruptured storage tank in New Brunswick in 1969. It is believed that 10,000 to 15,000 harp seals were coated with oil but the exact number of dead seals recovered is unknown (Sergeant 1991). The release of fuel oil from the *Arrow* into Chedabucto Bay, Nova Scotia in 1970 resulted in the fouling of 500 seals within the bay and 50 to 60 harbour and 200 grey seals on Sable Island (200 km south of the spill). Twenty-four seals were found dead and some had oil in their mouths and stomachs (Anon. 1970; 1971 in St. Aubin 1990). Oiled grey and harbour seals were found on the coast of Nova Scotia and Sable Island again in 1979 when the oil tanker *Kurdistan* sank in Cabot Strait. No causal relationship between oiling and death was determined (Parsons et al. 1980 in St. Aubin 1990). No mortalities were reported after a well blowout near Sable Island in 1984 and only two oiled grey seals were observed (St. Aubin 1990).

Intensive and long-term studies were conducted after the *Exxon Valdez* spill in Alaska. There may have been a long-term decline of 36 percent in numbers of moulting harbour seals at oiled haul-out sites in Prince William Sound, following the *Exxon Valdez* spill (Frost et al. 1994). The seals were probably not displaced and the decline probably represents mortality. Harbour seal pup mortality at oiled beaches was 23 to 26 percent, which may have been higher than natural mortality (Frost et al. 1994). However, attributing cause to the decreasing trend in harbour seal numbers since the spill (4.6 percent per year) is complicated because seal populations were declining prior to the spill (Frost et al. 1999).

Avoidance and Behavioural Effects

There is conflicting evidence on whether seals detect and avoid spilled oil. Some oiled seals hauled out on land are reluctant to enter the water, even when disturbances from intense cleanup activities occur nearby (St. Aubin 1990; Lowry et al. 1994). In contrast, several thousand grey and harbour seals apparently left Chedabucto Bay, Nova Scotia, after the grounding of the *Arrow* (Mansfield 1970 in St. Aubin 1990), although this movement may have been caused by the increased human disturbance during cleanup activities rather than by the presence of oil (St. Aubin 1990). Harbour seals observed immediately after oiling appeared lethargic and disoriented, which may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994). Other seals have been observed swimming in the midst of oil spills (St. Aubin 1990). Oiling of both mother and pups does not appear to interfere with nursing (Lowry et al. 1994).

Oiling of External Surfaces

Adult and juvenile hair seals (includes harbour, grey, harp and hooded seals) are at virtually no risk of thermal regulatory effects from oil fouling because their blubber, not their fur, provides insulation (Kooyman et al. 1976; 1977; St. Aubin 1990). It is questionable whether young seal pups, which rely on their birth coat and brown fat stores, could survive the deleterious effects of oiling (St. Aubin 1990). Contact with oil on the external surfaces can cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith 1976; St. Aubin 1990). Harbour seals oiled during the *Exxon Valdez* spill had difficulty keeping their eyes open and experienced conjunctivitis (Spraker et al. 1994). These effects seem to be temporary and reversible, but continued exposure of oil to eyes could cause permanent damage (St. Aubin 1990). Damage to a seal's visual system would likely limit foraging abilities, as vision is an important sensory modality used to locate and capture prey (Levenson and Schusterman 1997). Mucous membranes that line the oral cavity, respiratory surfaces, and anal and urogenital orifices are also sensitive to oil exposure (St. Aubin 1990). Seals fouled externally with heavy oil may also encounter problems with locomotion. The flippers of young harp seals and grey seal pups were impeded by a heavy coating of oil that became stuck to their sides (Davis and Anderson 1976; Sergeant 1991). This led to the drowning of the grey seal pups. The coating of seals and their subsequent deaths were also observed in seals exposed to heavy bunker oil during the *Arrow* and *Kurdistan* spills (Engelhardt 1987 in Lowry et al. 1994).

Oil Ingestion and Inhalation

Seals can ingest oil if their food is contaminated or by nursing contaminated milk. Oil can also be absorbed through the respiratory tract (Geraci and Smith 1976; Engelhardt et al. 1977). Some ingested oil is voided in vomit/feces or metabolized at rates that prevent significant bioaccumulation (Neff 1985 in Hartung 1995) but some is absorbed and can cause toxic effects (Engelhardt 1981). These effects may include minor kidney, liver and brain lesions (Geraci and Smith 1976; Spraker et al. 1994). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978; 1982;

1985). Seals exposed to an oil spill and especially a blowout are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982) and any effects are probably reversible (Spraker et al. 1994). There were no significant quantities of oil in the tissues (liver, blubber, kidney and skeletal muscles) of harbour seals exposed during the *Exxon Valdez* spill (Bence and Burns 1995).

Seals are also at risk from hydrocarbons and other chemicals that evaporate from spills and blowout areas. Seals generally keep their nostrils close to the water surface when breathing, so they are likely to inhale vapours if they surface in a contaminated area. Grey seals that presumably inhaled volatile hydrocarbons from the *Braer* oil spill exhibited a discharge of nasal mucous, but no causal relationship with the oil was determined (Hall et al. 1996). Laboratory studies of ringed seals indicate that the inhalation of hydrocarbons may cause more serious effects like kidney and liver damage (St. Aubin 1990). However, exposure conditions were much higher than would be expected in a natural setting.

Factors Affecting the Severity of Oil Exposure

Seals that are under some type of natural stress, such as lack of food or a heavy infestation by parasites, could die as a result of the additional stress of oiling (Geraci and Smith 1976; St. Aubin 1990). Seals that are not under natural stress would most likely survive oiling.

Seals exposed to heavy doses of oil for prolonged periods of time could die. Harbour seals may be particularly at risk because they exhibit site fidelity (Boulva and McLaren 1979; Yochem et al. 1987). Prolonged exposure from oil at a preferred haul-out site could cause the death of some seals. Similarly, if concentrations of oil reached the beaches of St. Pierre or other breeding sites during the harbour seal breeding period (May to July) both adult and pup mortality could occur. However, Jenssen (1996) reported that oil has produced little visible disturbance to grey seal behaviour and there has been little mortality despite the fact that approximately 50 percent of grey seal pups at Norway's largest breeding colony are polluted each year by oil.

Summary

In general, cetaceans and seals do not exhibit large behavioural or physiological reactions to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil (St. Aubin 1990; Williams et al. 1994).

Effects predictions for an accidental event associated with the White Rose oilfield development on marine mammals are detailed in Section 5.9.2.3.

5.9.1.4 Sea Turtles

It is not known whether sea turtles can detect and avoid oil slicks. Gramentz (1988) reported that sea turtles did not avoid oil at sea, while sea turtles exposed to oil under experimental conditions had a limited ability to avoid oil (Vargo et al. 1986).

Loggerhead sea turtles experimentally exposed to oil had marked gross and histologic lesions present in the skin. Most effects were reversed by the tenth day following cessation of oil exposure (Bossart et al. 1995). Other effects of oil on sea turtles include reduced lung diffusion capacity, decreased oxygen consumption, decreased digestion efficiency, and damaged nasal and eyelid tissue (Lutz et al. 1989).

There are few field observations of sea turtles exposed to oil. After the Ixtoc 1 oil well blowout in 1979, seven live and three dead sea turtles were recovered (Hall et al. 1983). Two of the three carcasses had oil in the gut but no lesions. There was no evidence of aspirated oil in the lungs but hydrocarbon residues were found in kidney, liver, and muscle tissue of all three dead turtles. The authors suggested prolonged exposure to oil may have disrupted the feeding behaviour and weakened the turtles.

Effects predictions for an accidental event associated with the White Rose oilfield development on sea turtles are detailed in Section 5.9.2.4.

5.9.2 Potential Effects on Valued Environmental Components

Effects are assessed for each of the oil spill scenarios described in Section 5.8. Summer and winter scenarios are assessed together as the rankings for assessment categories are consistent across seasons.

5.9.2.1 Fish and Fish Habitat

A scenario approach was used to evaluate interactions between oil spills and water quality, plankton, fish eggs and larvae, juvenile fish, adult pelagic fish and adult groundfish (Table 5.9-1).

Table 5.9-1 Project-Environmental Interaction Matrix for Fish and Fish Habitat

Valued Environmental Component: Fish and Fish Habitat									
	Habitat			**Feeding**		**Reproduction**		**Adult Stage**	
	Water Quality	**Sediment**	**Topography**	**Plankton**	**Benthos**	**Eggs/Larvae**	**Juveniles**	**Pelagic Fish**	**Groundfish**
Offshore Blowouts/Spills									
Subsea blowout 7 day	x			x		x	x	x	x
Subsea blowout 45 day	x			x		x	x	x	x
Above-surface blowout 7 day	x			x		x			
Batch Spill 800 m^3	x			x		x			
Batch Spill 10,000 m^3	x			x		x			
Batch Spill 30,000 m^3	x			x		x			

Juvenile and Adult Fish

Carls et al. (1998) exposed wild adult Pacific herring in spawning condition to initial PAH concentrations as high as 0.058 ppm for 16 to 18 days. Although cumulative mortality rates for the three treatments at this concentration ranged from approximately 15 to 35 percent, causality of the continuous exposure was not proven. The highest average oil concentration in the upper 10 m at White Rose predicted by S.L. Ross is 0.0075 ppm, less than 15 percent of the highest treatment used by Carls et al. (1998). Marty et al. (1999) stated that adult Pacific herring in Prince William Sound, Alaska, were likely exposed to *Exxon Valdez* oil in April 1989, but that fish no longer had significant evidence of exposure in 1990. Pearson et al. (1999) concluded that there were no significant indications that the failure of the 1993 Pacific herring fishery in Prince William Sound could be attributed to the 1989 *Exxon Valdez* spill.

Juvenile and adult fish can and probably will avoid any crude oil by swimming from the blowout/spill region (Irwin et al. 1997). Effects of oil spills on adult and larval fish are predicted to be *negligible*. This conclusion is consistent with the findings in both the Hibernia and Terra Nova EIS. The Hibernia and Terra Nova EISs both concluded that neither surface spills nor subsea blowouts posed significant risks to either pelagic or demersal fish stocks (Mobil 1985; Petro-Canada 1995).

Eggs and Larvae

Interactions between oil spills and commercial fish, invertebrate eggs and larvae could affect fish populations. The results of recent ichthyoplankton surveys (Bonnyman 1981; Anderson and Dalley 1997; Dalley and Anderson 1998; Dalley et al. 1999) and studies of oil spill effect on fish eggs and larvae (Hurlbut et al. 1991) were used to select eight fish species to evaluate the effects of the six blowout and spill scenarios. They are sand lance, redfish, capelin, American plaice, yellowtail flounder, Atlantic cod, haddock, and witch flounder. The eggs and larvae of these eight species are known to occur in the White Rose area, account for the vast bulk of the ichthyoplankton, and could be exposed to oil releases in the area. The environmental effects of all six scenarios on the eggs and larvae are predicted to be *adverse* because of potential lethal and sublethal effects to these sensitive life stages (Table 5.9-2).

The geographical and seasonal distribution of fish eggs and larvae on the Grand Banks is highly variable (see Section 3.6 for a detailed description). Generally, there are two peaks in abundance of ichthyoplankton on the Grand Banks. The first is in April-May, which is typically dominated by sand lance and redfish on the slopes and in the deepwater off the slope. The second peak tends to occur in August-September on the central Grand Banks and Southeast Shoal region. Eggs and larvae of capelin and flatfish are dominant at this time. There is much variability in the timing of the peaks and in the abundance of various species. The collapse of numerous fish stocks during the past 10 years has resulted in even more variability in abundance and distribution. Generally, most fish eggs and larvae are concentrated in the upper 50 m of the water column.

Table 5.9-2 Environmental Effects Assessment for Fish and Fish Habitat

Valued Environmental Component: Fish and Fish Habitat									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Commercial Finfish & Invertebrate Eggs/Larvae									
Subsea blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Subsea blowout 45 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Water Quality									
Subsea blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Subsea blowout 45 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Above-surface blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Plankton									
Subsea blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Subsea blowout 45 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1

Valued Environmental Component: Fish and Fish Habitat									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Above-surface blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	2	R	1

KEY:

Magnitude:	**Geographic Extent:**	**Frequency:**	**Duration:**	**Reversibility:**
0 = negligible	1 = <1 km²	1 = < 11 events/yr	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km²	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km²	3 = 51-100 events/yr	3 = 13-36 months	
3 = High	4 = 101-1000 km²	4 = 101-200 events/yr	4 = 37-72 months	
	5 = 1001-10,000 km²	5 = >200 events/yr	5 = > 72 months	
	6 = >10,000 km²	6 = continuous		

Ecological/Socio-cultural and Economic Context:

1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

a Geog. Extent differed during summer & winter but always fell within the same category of Geog. Extent.
b Effects on individuals irreversible but any population effects are likely reversible.

The maximum dispersed oil concentration (0.0075 ppm) in the upper 10 m of the water column was predicted for the seven-day above-surface blowout, summer scenario. This can be considered the 'worst case scenario' in terms of oil concentrations in the water column. (see Section 5.8 for scenario details). Predicted dispersed oil concentrations in the water column are low due to the high persistence of White Rose crude, the oil's tendency to form stable emulsions, and because of its high pour point. The predictions assume that the oil is equally dispersed throughout the top 10 m of water column. This value, 0.0075 ppm, is well below levels in the literature that are consistently shown to have effects on fish and invertebrate eggs or larvae, particularly lethal effects (Moore and Dwyer 1974; Kocan et al. 1996; Marty et al. 1997). Recent unpublished laboratory studies indicate that low levels of sublethal effects can occur after continuous exposure of fish eggs (fertilization to hatching) to PAHs at concentrations below 0.0075 ppm (Marty et al. 1997).

The conclusions reached during the oil blowout/spill impact assessments for the Hibernia and Terra Nova EISs and a study of effects of oil spills on Grand Banks eggs and larvae by Hurlbut et al. (1991) are that negligible effects on ichthyoplankton would occur under the worst-case scenarios. The lowest of three crude oil LC_{50} concentration used by Hurlbut et al. (1991) in their spill scenarios was 0.143 ppm, almost 20 times the maximum 10-m subslick concentration predicted for White Rose.

The magnitude of effects on fish eggs and larvae would be *negligible to low* for each finfish and invertebrate species in each blowout/spill scenario (Table 5.9-2). Geographic extent for all blowout scenarios is *greater than 10,000 km*^{2} while for all spill scenarios it is *1,001 to 10,000 km*^{2} based on the modelling. The geographic extent of any measurable effects will actually be much less than the areas shown because concentrations of oil in the water column will likely be lower than those shown to produce demonstrable effects. Predicted frequency of large spills is *much less than 1 event/yr*, duration is *1 to 12 months*, and environmental effects on the fish eggs/larvae in all scenarios are deemed *reversible* at the population level.

Considering that all magnitude ratings were *negligible to low* (Table 5.9-2), all predicted adverse environmental effects on fish eggs/larvae will be *not significant* (Table 5.9-3), as was predicted in the Hibernia and Terra Nova EISs. The likelihood of an accidental event, as summarized in Section 5.7, is extremely low.

Effects on Fish Habitat

Short and Harris (1996) sampled seawater in Prince William Sound at 1 and 5 m depths within the six week period following the *Exxon Valdez* spill. The highest PAH concentration found was 0.00159 ppm, well below levels considered acutely toxic to marine fauna. Effects on plankton are short-lived and zooplankton are more sensitive than phytoplankton (in Irwin et al. 1997). The Hibernia and Terra Nova EISs predicted that environmental (biophysical) effects on water quality and habitat would be *not significant*. Effects of spills on fish habitat at the White Rose site would also be *not significant*. The likelihood of an accidental event, as summarized in Section 5.7, is extremely low.

Table 5.9-3 Significance of Predicted Residual Environmental Effects on Fish and Fish Habitat in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout

Valued Environmental Component: Fish and Fish Habitat				
Accidents	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Oil Blowouts/Spills	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Subsea blowout 7 day	NS	3	1	3
Subsea blowout 45 day	NS	3	1	3
Above-surface blowout 7 day	NS	3	1	3
Batch Spill 800 m^3	NS	3	1	3
Batch Spill 10,000 m^3	NS	3	1	3
Batch Spill 30,000 m^3	NS	3	1	3

Key:

Residual Environmental Effect Rating:

S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) *and* geographic extent >100 km^2 (4 or greater rating).

Level of Confidence in Impact Prediction

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability

1 = Low Probability
2 = Medium Probability
3 = High Probability

Scientific Certainty: Based on Scientific Information and Statistical Analysis or Professional Judgement

1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

N/A = Not Applicable

5.9.2.2 Marine Birds

Birds are affected by exposure to oil, and most birds that come in contact with a marine oil spill subsequently die. As significant numbers and concentrations of birds occur on the Grand Banks of Newfoundland, any oil spill or blowout could cause at least some and, at worst, extensive bird mortality. These potential effects are confounded by the physical properties of White Rose crude oil. The waxy nature of the oil slows evaporation and dispersion, causing the oil to maintain its volume and persist on the surface of the water. The oil may last for several weeks or even months before the particles and patches diffuse and dilute to levels that would not affect seabirds. On the other hand, the waxy oil particles become semi-solid within a short period of time after release and may not wet birds' feathers in the same way as conventional, non-waxy oils. Major changes in the oil's spreading behaviour and its ability to wet birds' feathers will certainly reduce the potential effect of spills on birds. However, until the potential effects of White Rose oil on seabirds are better understood, it is conservative to assume that the risks to birds are similar to those from a conventional oil.

Distribution and density data for seabirds are limited in the study area, especially for the areas where spilled oil is likely to occur (see Figures 5.8-1 to 5.8-12), so no attempt was made to quantify potential bird mortalities. Large numbers of seabirds could be killed by an accidental release of hydrocarbons at White Rose. Oil spills have the greatest effects on marine bird populations if the spill occurs at a time and place where birds are concentrated, such as near feeding/staging/moulting aggregation areas or nesting colonies.

It is extremely unlikely that crude oil accidentally spilled at the White Rose site will reach any seabird colonies in the study area. None of the 14,600 individual model runs for this assessment predicted oil onshore. The March/April predictions came closest (within 150 km) to shore but still did not predict any oil onshore (Figures 5.8-3 and 5.8-4). Seabirds have not yet begun to lay their eggs during March/April, so there is little chance of eggs becoming contaminated with oil. Any small amounts of oil that strand initially would be re-suspended and further dispersed by winter waves and storms before most birds arrived at their nesting sites in the spring. Also, the seabird colonies in the study area generally consist of steep, rocky shores exposed to high-energy wave action. Any oil stranded on these shores would be quickly dispersed by waves and heavily weathered, probably in the form of non-sticky tar balls. Most importantly, however, the oil would be very widely dispersed so that the average amount of oil stranding on shore would be negligible. Once again, the results of the oil spill trajectory models indicate that oil accidentally released at the White Rose site will not reach the shores of Newfoundland.

The oil spill trajectory models indicate that small areas near the spill site have a high probability that oil will occur there. Seabirds are known to associate with offshore structures and these birds are at increased risk to exposure in the unlikely event of an accidental release of oil. During summer, shearwaters, gulls (including kittiwakes), storm-petrels, and fulmars would be the species most likely exposed to oil near the release point. These species are vulnerable to contacting oil because individuals have frequent contact with the water's surface. Alcids are at an even greater risk to oiling, especially in winter, but it is uncertain whether this group associates with offshore structures to the same degree as shearwaters, gulls, storm-petrels, and fulmars.

After the oil moves away from the release point, the oil spill trajectory models predict that oil will likely be found east and southeast of the White Rose release point. It is unlikely that oil will move into the central and western portions of the Grand Banks. Oil may occur on and south of the Flemish Pass and Cap, especially during the summer months. This could expose many species of seabirds to oil, but fulmars, shearwaters, black-legged kittiwakes, storm-petrels, and dovekies would be at greatest risk. During May and June (Figures 5.8-5 and 5.8-6), there is an increased likelihood (still relatively low) that oil will be found along the southwestern depth contours of the Grand Banks. Oil will probably not extend into the southeast shoal, so the large numbers of greater shearwaters and Wilson's storm-petrels, and smaller numbers of sooty shearwaters, that moult and forage there during the summer would not be exposed to oil.

During winter, large numbers of alcids, most notably thick-billed murres and dovekies, could die from exposure to oil from an accidental spill or blowout at the White Rose site. The exact location of their wintering areas is unknown and likely varies from year to year. It is possible that oil could pass through a substantial portion of these wintering areas, thereby killing large numbers of alcids.

Depending on the time of year, location of seabirds within the study area, and type of oil spill or blow-out, the impacts of an offshore oil release could range from a *low* to *high* magnitude, a geographic extent of *1001-10,000* km^2 for batch spills to *>10,000* km^2 for both above-surface and subsea blowouts, and a duration of *1-12 months* (Table 5.9-4). The estimates for 'geographic extent' are conservative because a slick will not cover a continuous area by the end of the 30-day modelling period but rather, a large number of small mats, particles, and "wax" balls interspersed with areas where there is no oil. Nonetheless, there could be *significant* adverse effects on marine birds from any batch spill or blowout at the White Rose site (Table 5.9-5). Similar predictions were made in the Hibernia and Terra Nova EISs regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1995).

The oil spill countermeasures described in the contingency plan would likely reduce the number of oiled seabirds, but *significant* adverse effects are still likely even after countermeasures are imposed. Any effects of oil exposure on individual seabirds would be *irreversible* and any rehabilitation attempts would likely be unsuccessful (see Section 5.9.1.2, Rehabilitation). It is likely that any effects at the population level would be *reversible* over time. Therefore, because the significant adverse effect is reversible, in the unlikely event that is occurs, the population of marine birds, which is a renewable resource, will be able to meet future needs of resource users. Because only a portion of the offshore population is hunted inshore, the present needs would not be compromised. The reader should note that there is an extremely low probability that a major oil spill or blowout will occur at the White Rose site. Given the risk statistics summarized in Section 5.7, it is extremely unlikely that an accidental event of a magnitude to affect population numbers over generations will occur. In addition, the mitigation of proactive contingency planning outlined in Chapter 6 will further minimize the risk of an oil spill occurring.

Table 5.9-4 Environmental Effects Assessment for Marine Birds, Marine Mammals, and Sea Turtles in the Unlikely Event of an Offshore Oil Spill and Blowout

Valued Environmental Component: Marine Birds, Marine Mammals, and Sea Turtles									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario [a]	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
A. MARINE BIRDS									
Subsea blowout 7 day	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I [b]	1
Subsea blowout 45 day	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I [b]	1
Above-surface blowout 7 day	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	6	<1	2	I [b]	1
Batch Spill 800 m^3	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I [b]	1
Batch Spill 10,000 m^3	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I [b]	1
Batch Spill 30,000 m^3	Mortality (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	1-3	5	<1	2	I [b]	1
B. MARINE MAMMALS									
Subsea blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1
Subsea blowout 45 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1
Above-surface blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1
C. SEA TURTLES									
Subsea blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1
Subsea blowout 45 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1

Valued Environmental Component: Marine Birds, Marine Mammals, and Sea Turtles										
Accidental Offshore Oil Spill or Blowout										
				Evaluation Criteria for Assessing Environmental Effects						
VEC and Spill Scenario [a]	**Potential Positive (P) or Adverse (A) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Above-surface blowout 7 day	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	6	<1	2	R	1
Batch Spill 800 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1
Batch Spill 10,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1
Batch Spill 30,000 m^3	Effects on Health (A)	Contingency Plan	Training, Preparedness, Prevention, Cleanup Inventory	0-1	5	<1	2	R	1

KEY:

Magnitude:
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:
1 = < 11 events/yr
2 = 11-50 events/yr
3 = 51-100 events/yr
4 = 101-200 events/yr
5 = >200 events/yr
6 = continuous

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility:
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

[a] Geog. Extent differed during summer & winter but always fell within the same category of Geog. Extent.
[b] Effects on individuals irreversible but any population effects are reversible.

Table 5.9-5 Significance of Predicted Residual Environmental Effects on Marine Birds, Marine Mammals, and Sea Turtles in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout

Valued Environmental Component: Marine Birds, Marine Mammals, and Sea Turtles				
VEC and Spill Scenario[a]	**Significance Rating**	**Level of Confidence**	**Likelihood**	
	Significance of Predicted Residual Environmental Effects		**Probability**	**Scientific Certainty**
A. MARINE BIRDS				
Subsea blowout 7 day	S	3	1	3
Subsea blowout 45 day	S	3	1	3
Above-surface blowout 7 day	S	3	1	3
Batch Spill 800 m^3	S	3	1	3
Batch Spill 10,000 m^3	S	3	1	3
Batch Spill 30,000 m^3	S	3	1	3
B. MARINE MAMMALS				
Subsea blowout 7 day	NS	2	1	2
Subsea blowout 45 day	NS	2	1	2
Above-surface blowout 7 day	NS	2	1	2
Batch Spill 800 m^3	NS	2	1	2
Batch Spill 10,000 m^3	NS	2	1	2
Batch Spill 30,000 m^3	NS	2	1	2
C. SEA TURTLES				
Subsea blowout 7 day	NS	1	1	1
Subsea blowout 45 day	NS	1	1	1
Above-surface blowout 7 day	NS	1	1	1
Batch Spill 800 m^3	NS	1	1	1
Batch Spill 10,000 m^3	NS	1	1	1
Batch Spill 30,000 m^3	NS	1	1	1

KEY:

Residual Environmental Effects Rating:
S = Significant Adverse Environmental Effect
NS = Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Significance is defined as a med. or high magnitude effect, for a duration >1 yr, and a geographic extent >100 km^2.

Probability of Predicted Effect Occurring: based on professional judgement
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Level of Confidence in Effect Prediction:
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

[a] Geographical Extent differed during summer and winter but always fell within the same category of Geographical Extent.

5.9.2.3 Marine Mammals

Cetaceans

Whales are not considered to be at high risk to the effects of oil exposure. There is no clearcut evidence that implicates oil spills with the death of cetaceans. Both toothed and baleen whales present in the study area could suffer sublethal effects, through oiling of mucous membranes or the eyes if they swim through a slick. As discussed above, these effects are reversible and would not cause permanent damage to the animals. There is a possibility that the baleen of whales could be contaminated with oil, thereby reducing filtration efficiency. However, effects would be minimal and reversible. Also, there is little chance that oil will reach the southeast shoal of the Grand Banks, where baleen whales like humpbacks are known to concentrate to feed on capelin. Whales are present on the offshore portions of the Grand Banks in low numbers at certain times of the year. Therefore, only small proportions of populations are at risk at any time.

Depending on the time of year, location of toothed and baleen whales within the study area, and type of oil spill or blowout, the effects of an offshore oil release could range from a *negligible* to *low* magnitude, a geographic extent of *1001-10,000 km*^{2} for batch spills to *>10,000 km*^{2} for both above-surface and subsea blowouts, and a duration of *1-12 months* (Table 5.9-4B). The estimates for 'geographic extent' are conservative because a slick will not cover a continuous area by the end of the 30-day modelling period, but rather a large number of small mats, particles, and "wax" balls interspersed with areas where there is no oil. There will be a not significant adverse effect on cetaceans from an accidental release of oil at the White Rose site (Table 5.9-5B). Similar predictions were made in the Hibernia and Terra Nova EISs regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1995).

The oil spill countermeasures described in the contingency plan and associated disturbance would likely reduce the number of whales exposed to oil.

Seals

Seals are not considered to be at high risk from the effects of oil exposure, but some evidence implicates oil spills with seal mortality, particularly young seals. As previously discussed, seals are present on or near the Grand Banks for at least part of the year. The majority of those present are associated with the edge of the pack ice. In average years, the ice edge extends no nearer than several hundred kilometres to the north of the White Rose area and then only for several months of the year. The oil spill trajectory models indicate that after the oil moves away from the release point, it will likely be found east and southeast of the White Rose release point. Therefore, it is highly unlikely that oil accidentally released at the White Rose site will reach the ice edge during years with "average" ice conditions. In the years of heaviest ice, the pack ice extends southward as far as the White Rose area, but for only a few weeks of the year. There is a possibility that oil will contact the southern edge of the pack ice for a few weeks during years of heavy ice conditions, but seals are less common on the deteriorating southern extremities of the ice edge than they are farther north. Few seals are expected to be exposed to oil from an accidental release at the White Rose site and most seals do not exhibit large behavioural or physiological reactions to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on seals could range from a *negligible* to *low* magnitude, a geographic extent of *1001-10,000* km^2 for batch spills to *>10,000* km^2 for both above-surface and subsea blowouts, and a duration of *1-12 months* (Table 5.9-4B). The estimates for 'geographic extent' are conservative because a slick will not cover a continuous area by the end of the 30-day modelling period, but rather a large number of small mats, particles, and "wax" balls interspersed with areas where there is no oil. There will be no significant adverse effects on seals from an accidental release of oil at the White Rose site (Table 5.9-5B). Similar predictions were made in the Hibernia and Terra Nova EISs regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1995).

The oil spill countermeasures described in the contingency plan would likely reduce the number of seals exposed to oil.

5.9.2.4 Sea Turtles

Sea turtles are rare on the Grand Banks and particularly rare in the cold water of the White Rose area. Although there are no reliable data on sea turtle abundance and distribution on the Grand Banks, at-sea observer data collected by the U.S. National Marine Fisheries Service (NMFS) for the pelagic longline fishery provide some insight.

The major threats to sea turtle survival include disturbance and destruction of sensitive reproductive habitat on subtropical and tropical sandy beaches, ingestion of floating plastic debris, and commercial fisheries. In the Grand Banks area, sea turtles are caught incidental to the pelagic longline fishery directed at tunas, swordfish and sharks (NOAA 2000). During the period 1995-98, the U.S. pelagic longline fleet caught at least 201 sea turtles in the Northwest Atlantic in the vicinity of the Grand Banks, the vast majority of which were released alive (Appendix Table A2 in NOAA 2000). The at-sea observer data indicate that the sea turtles are highly associated with very warm (>20°C) water (NOAA 2000). On the Grand Banks, turtles are most likely to be associated with eddies spun off from the Gulf Stream. There are no known persistent eddies in the White Rose area (J. Bobbitt, pers. comm.).

Because sea turtles breathe at the surface and are visual predators that feed near the surface, they may be vulnerable to a surface oil slick. Effects can be caused by smothering, inhalation of fumes, or ingestion. Relatively few sea turtles have been collected after oil spills (for example, three after IXTOC blowout and two after the Berman spill (Hall et al. 1983; Mignucci-Giannoni 1999)) and only 1 percent (3 to 6 percent in South Florida and Texas) of turtle strandings in the U.S. are attributable to oil (Lutcavage et al. 1997). This suggests that either turtles suffer little immediate mortality or the corpses are not readily collected. Probably the greatest threats to sea turtles from oil on the surface are sublethal effects because they may not be able to detect and avoid spills and laboratory studies have shown that they pursue tar balls as if they were prey (Lutcavage 1997).

In general, the potential for the White Rose activities to interact with sea turtles is very small because they are rarely present; in addition, they are probably only present in any significant numbers during summer and fall, and they are highly associated with very warm water.

There is a very low likelihood that sea turtles will be exposed to oil from an accidental release at White Rose. Effects of oil on sea turtles will be reversible, but there is a possibility that foraging abilities may be inhibited by exposure to oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on sea turtles could range from a *negligible* to *low* magnitude, a geographic extent of *1001-10,000* km^2 for batch spills to *>10,000* km^2 for both above-surface and subsea blowouts, and a duration of *1-12 months* (Table 5.9-4C). The estimates for 'geographic extent' are conservative because a slick will not cover a continuous area by the end of the 30-day modelling period but rather a large number of small mats, particles, and "wax" balls interspersed with areas where there is no oil. There will be a not significant adverse effect on sea turtles from an accidental release of oil at the White Rose site (Table 5.9-5C).

The oil spill countermeasures described in the contingency plan may reduce the number of sea turtles exposed to oil.

5.9.2.5 Cumulative Effects of Accidental Events

Given that the likelihood of an oil well blowout or a significant oil spill occurring at White Rose is extremely low (Section 5.7), it is highly unlikely that simultaneous accidental events would concurrently occur at Hibernia, Terra Nova or White Rose. With three operating fields on the Grand Banks, the risk of an accidental occurrence increases to approximately four times that of it occurring at White Rose (S.L. Ross, pers. comm.). However that risk is still extremely low.

5.9.3 Follow Up and Monitoring

In the unlikely event of a major spill, Husky Oil commits to conducting an EEM program to test specific hypothesis generated by this effects analysis. An oil spill-specific EEM design will be submitted to the regulatory agencies for review.

6 MITIGATION MEASURES AND CONTINGENCY PLANNING

6.1 SCOPE OF PLANNING

Prior to commencement of production operations, Husky Oil will develop contingency plans that will serve as the guides for the company's response to any emergency encountered during the White Rose production. Plans will be developed to address emergencies that could potentially be encountered based on operations-specific hazard/risk analysis. The plans will outline the necessary personnel, equipment, and logistics support along with procedures to implement initial actions to respond to an emergency incident in a safe, prompt, coordinated manner. The plans will be distributed to designated personnel who will be responsible for emergency response actions. The content of the plans will contain sufficient detail to enable personnel to respond in a coordinated and effective manner.

6.1.1 Geographic Area Covered by Planning

Emergency response planning for White Rose production operations will focus on the area immediately adjacent to the location of the potential emergency which in most cases is the production site or satellite drill sites. This area will be defined as the safety zone (refer to Figure 4.3-1) established around the production site to ensure collision avoidance with ocean-going vessels. This is the area that will be administered by the C-NOPB.

The safety zone will be recognized by Transport Canada, who will publish a description of this area for the information of all ocean-going traffic. Based on the precedent set by Terra Nova, Husky Oil will apply for a 5-nautical mile (9.3 km) safety zone around the FPSO production location.

6.1.2 Husky Oil Corporate Policy

Husky Oil maintains a strong commitment to health, safety and environmental stewardship. The company conducts its business activities with a progressive approach and is committed to monitoring and improving its performance. Central to this commitment is a corporate Health, Safety and Environment (HS&E) Management System, which governs all aspects of loss control management.

6.1.3 Husky Oil Corporate Contingency Planning

As part of the corporate HS&E Management System, Husky Oil has developed a company-wide approach to contingency planning. All Husky Oil facilities, both in western Canada and offshore operations, are equipped with emergency response plans and procedures that share common format and approaches. Each plan reflects conditions and is risk specific to each facility but is similar enough to plans for other facilities that it may be quickly implemented by any trained Husky Oil personnel.

Husky Oil will use the same philosophy and approach that it uses throughout the company when developing contingency plans for the proposed White Rose offshore oilfield development. In addition to environmental protection plans (including environmental compliance, monitoring and environmental effects monitoring programs) to be developed specifically for all phases of White Rose production operations, Husky Oil will update and modify its existing offshore ice management and emergency response plans for use in production operations. Specifically, general emergency response procedures that have been developed for delineation drilling in 1999 will be updated and expanded for use during production operations. Facility-specific alert and emergency response procedures and vessel-specific contingency plans will also be developed to cover the details of local response procedures.

6.1.4 Emergencies Covered by White Rose Contingency Planning

An emergency will be defined as any unexpected occurrence resulting or having the potential to result in:

- death or serious injury/illness requiring hospitalization;
- an environmental effect posing serious threat to on-scene personnel, third-party personnel, marine life or wildlife; or
- major or substantial damage to operator or contractor property.

Several types of emergencies will be covered by White Rose contingency plans. The response to any of the following incidents will require immediate notification and action:

- accidental injury;
- explosion or fire;
- loss of well control;
- hydrocarbon or chemical spills;
- loss of or damage to aircraft supporting production operations;
- loss of or damage to support or standby vessels;
- loss or disablement of the FPSO or MODU, including ballast control or stability problems;
- major damage to equipment not caused by any of the above (for example, materials handling, equipment failure, or operator error);
- imminent threat to operations posed by weather, sea ice, or icebergs;
- collision or threat of collision with an ocean-going vessel;
- diving incidents;
- threatened or actual damage to subsea pipelines or well centre hardware; and
- security-related incidents such as extortion, bomb threat, or criminal or terrorist acts.

6.1.5 Proposed Contingency Plan Development

Contingency planning for the White Rose development will be addressed in a number of inter-related documents, each of which will cover a specific aspect of response operations. An overview of the individual documents that, collectively, will dictate all emergency response operations is presented in Table 6.1-1. The plan names used in Table 6.1-1 are generic. The structure and naming of each plan will be finalized during the development of the White Rose production program.

Table 6.1-1 Overview of Contingency Plans to be Developed for the White Rose Project

Plan	Description
HS&E Loss Control Management System	• a series of policies and procedures requiring activities to be carried out so as to prevent the occurrence of emergency incidents.
Offshore Emergency Response Procedures	• directs on-site actions at the White Rose site (including production operations at the FPSO and production drilling at the MODU); • provides very specific actions for supervisory and technical response personnel for a number of potential emergencies; • provides a link between all offshore facilities (FPSO, MODU, and support vessels); and • communication to area operators and regulatory first responders.
Alert and Emergency Response Plan	• integrates overall response actions; • directs actions of shore-based Emergency Response Team; • provides general management procedures for any emergency; • allows for increasing shore and corporate responsibility as an incident escalates; • provides the link between offshore actions (coordinated by FPSO Offshore Installation Manager (OIM)) and corporate emergency teams; and • communication to area operators and regulatory responders.
Collision Avoidance Plan	• a specific plan for ! identifying all potential collision situations involving the FPSO or MODU, ! communications with the threatening vessel, and ! prompt relocation of the offshore platform in the event that the threatening vessel does not change course; • includes an expanded multi-level traffic control area regulated by the FPSO; and • developed specifically for offshore use and directly related to the Offshore Emergency Response Procedures.
Ice Management Plan	• a plan that describes the procedures for ! monitoring the movement of icebergs that might pose a threat to drilling and production activities, and ! determining the need for specific countermeasure operations, including iceberg deflection or moving the platform off location; • the plan provides a link between all ice management operations offshore and on-shore; and • the plan provides a link between Husky Oil and other operators.
Oil Spill Response Plan	• procedures developed specifically for the response to oil spills originating from the White Rose production site; • covers situation where Husky Oil is the responsible party; • applies for both C-NOPB and *Canada Shipping Act* jurisdictions; • covers ! specific actions to be taken by platform and support vessel personnel,

Plan	Description
	! management or coordination actions taken by shore-based company and contractor personnel, and ! specific strategies for the response to anticipated oil spill scenario situations; • the plan provides a link between all spill response operations offshore and on-shore; • details procedures for spill response management (ISC-based) when an incident escalates above Stage 1; • the plan provides a link between Husky Oil and other operators; and • directly related to the FPSO or MODU SOPEP, Offshore Emergency Response Plan, and the Alert and Emergency Response Plan.
Ship's Oil Pollution Emergency Plans (SOPEP)	• individual oil spill response plans developed for each of the vessels contracted by Husky Oil for offshore production-related activities; • will apply when vessel is not at the production and is under the jurisdiction of the *Canada Shipping Act*.
Family Support Plan	• a plan to assist family members and friends of offshore personnel during an emergency situation; • description of the operation of a family information service and a family support centre; • protocols for contacting family members in a constructive and proactive manner; and • guidelines for volunteer family responders in how to deal with concerned relatives and friends.
Emergency Communications Plan	• a comprehensive guide to all communications with affected individuals, the public, and the media during an emergency response; • description of the operation of a media response centre; • news release and statement templates; • sample media questions and answers; • media information packages; and • directly linked to Corporate Plan.
Action Plans and Standard Operating Procedures	• set procedures for specific technical activities undertaken by Emergency Action Teams.
Corporate Emergency Notification Procedures	• Overall Husky Corporate Response Plan and Procedures outlining senior management and specialized corporate support department response to an emergency.

6.1.6 Plan Description

Because of the similarity in the construction of all Husky Oil contingency plans, the White Rose plan structures will be generic. Emergency response plans will outline management and operational procedures only. Procedures for the technical response to many of the above emergencies (medical, fire fighting, well control, ice management, spill response, equipment repairs, etc.) will be outlined in specific manuals and Standard Operating Procedures (SOPs) intended for the training and direction of designated Emergency Action Teams (EAT).

Most emergencies, however serious, will be of short duration and require a concentrated response involving a limited amount of resources. The exception will be the response to a major oil spill, which may require the mobilization of considerable equipment, vessel, and personnel for an extended period of time. Because of the complexity of oil spill response preparations and because of the environmental implications of a major oil spill, this review of White Rose contingency planning will include a detailed section on oil spill response management and countermeasures (Section 6.10).

Response Considerations

Response to all incidents will be carried out in a consolidated integrated fashion. Each person involved in emergency response will know their emergency response role thoroughly, and will be fully conversant with the roles of others with whom they will interact.

Specific considerations will apply to specific situations. Examples include:

- Personal Injury or Fatality

  Notwithstanding that every effort will be made to avoid accident or injury to personnel, such events may occur in the offshore environment. These can range from injuries of a minor nature that can be treated offshore, through serious injuries that necessitate transfer to an onshore facility, and in the worst case personnel fatality.

  An offshore medic trained in trauma response will be provided on the FPSO and on the MODUs. This person will have the support, when required, of other personnel trained in advanced first aid and medical escort service. The emergency medical team will complement the medic, to the extent appropriate, with the following additional personnel:

  - Level 1 first aid attendants on the FPSO and MODUs and support vessels, trained to provide first response and basic first aid,
  - Level 2 first aid attendants on the FPSO and MODUs and support vessels, trained to provide more advanced first aid to the more seriously injured as needed,
  - A shore based designated on call physician trained in offshore oil and gas related emergencies available for medical consultation on a 24 hour basis.

  The onboard sick bay will be supplied with all equipment and medical supplies necessary to provide immediate first aid.

- Fire or Explosion

  Passive and active protection systems will be designed into the FPSO to mitigate as much as possible the potential effects of fire or explosion.

  The fire detection system, whether automatically or manually activated, will initiate response to the fire or explosion, activating water deluge, foam, or carbon dioxide protective systems.

  Trained fire teams will supplement the protective systems. All personnel will receive comprehensive training in fire team duties. The teams' state of readiness will be kept at top level by regular drills. Exercises simulating major emergencies will be carried out on a regular basis. To ensure optimum ability to respond to major offshore emergencies, support vessel crews and onshore personnel will also be trained in offshore emergency response.

- Vessel Collision and Structural Impairment

  If, notwithstanding all vessel avoidance procedures, there is a collision between the FPSO and another vessel, structural impairment to some degree will be likely. Production will, in such instance, be immediately suspended pending an assessment of the damage sustained to the FPSO.

  The OIM will decide what action should be taken after the degree of damage is assessed. Depending on the extent of damage, this may vary from a decision to resume production, through various intermediate choices, up to a decision to evacuate the FPSO.

  All FPSO personnel will carry out weekly muster and lifeboat drills, and it will be a prerequisite for all offshore personnel to be trained in basic sea survival before going offshore. A selected number of offshore personnel will be trained as lifeboat coxswains.

- Heavy Weather

  Heavy weather is deemed to apply when topside facilities have to be shut down due to vessel motion.

  The OIM will take appropriate precautions in advance of the arrival of heavy weather. Producing systems will also be shut down in a controlled fashion. Wells will be shut in, tankers disconnected, cranes secured, and compressors shut down. If production is expected to be shut down for an extended period of time, the flowlines may be flushed to mitigate hydrate and/or pour point problems.

  The OIM will be responsible for all decisions concerning courses of action during heavy weather.

- Loss of Well Control

  Loss of well control, while unlikely, is more likely to occur during work being carried out from a drilling unit. This would include such activities as drilling, well completion or well workover. Therefore, in the event of loss of well control, remedial action will be implemented by the affected drilling unit in accordance with drilling and well control procedures. If circumstances so dictate, oil spill response action will also be implemented.

- Loss of Vessels or Helicopters

  All vessels and helicopters will be required to advise the onshore flight-tracking centre and offshore facilities of their position and status on a regular basis. In the case of aircraft, reporting will be required every 15 minutes. In the event that any vessel or helicopter becomes distressed, these reports will help identify its location, and hence improve the speed with which aid can be brought to the scene.

  In the event that such aid is required, all available resources will be immediately assigned to proceed to the last estimated location of the distressed unit.

  All search and rescue organizations will be immediately contacted and appropriate communication channels established. A command centre will be set up at to assist the search and rescue operation.

- Subsea Flowline or Manifold Leaks

  Monitoring of subsea flowlines and manifolds will be carried out by pressure instrumentation and by visual monitoring (ROV).

  In the event that a leak is detected, action will be taken immediately to shut in the flowline or manifold affected. If necessary, oil spill contingency response will be implemented.

- Diving Emergencies

  Diving activities in the field require close coordination with all operations currently occurring on the FPSO. Ongoing diving activities will require the suspension of all over-the-side work, restriction of offloading of supply vessels, and strict monitoring of suction inlets and discharge outlets.

  In the event of a diving emergency, the field diving superintendent will coordinate the emergency response. The FPSO OIM will provide coordinated support assistance from FPSO resources on request from the diving superintendent. As well, other field resources, such as vessels and helicopters, will be assigned as appropriate to assist on the request of the diving superintendent.

Vessel Surveillance and Collision Avoidance

Ocean-going vessels transiting the area of offshore operations may pose a threat to the moored FPSO or anchored MODUs. The crews of the FPSO, each MODU and each standby vessel will be required to maintain radar watch at all times to monitor vessel traffic in proximity to the FPSO and MODUs, and to react should the possibility of collision develop. The success of any anti-collision system is dependent on early warning and fast, efficient reaction.

The primary objective of collision avoidance procedures will be to ensure that every possible effort is made to avert a collision between the approaching vessel and the FPSO or MODU, and that the approaching vessel is alerted as early as possible to take avoidance action. The FPSO, MODU, or standby vessel may attempt to attract the attention of the approaching vessel in any one or more of the following ways:

- establishing radio communication;
- shining searchlights in the direction of the approaching vessel and then towards the FPSO or MODU, whichever is threatened;
- firing suitable pyrotechnics;
- signal light of the threatened vessel, FPSO or MODU, flashing "U";
- foghorn or whistle of the threatened vessel, FPSO or MODU, sounding "U";
- using onboard equipment, such as sirens, klaxons or concussive noisemakers;
- making use of international GMDSS procedures and frequencies; and
- other means at the discretion of the OIM.

Zones will be established, centred on the FPSO or MODUs, as follows:

- **Collision Zone** is bounded by a circle of radius 500 m (0.27 nautical mile). Any approaching vessel which has a closest point of approach (CPA) within, or at the perimeter of, this zone will trigger a collision alert for the threatened FPSO or MODU; and
- **Near Miss Zone** is a circular zone having its inner boundary at the perimeter of the Collision Zone (500 m) and its outer boundary at 2.0 nautical miles from the subject FPSO or MODU. The procedures will reflect that a near miss situation has the potential to develop rapidly into a collision situation.

The degree of action initiated, when the trajectory of an approaching vessel is projected to intrude into one of the zones, will be determined by the proximity of the CPA to the threatened facility and the time for the approaching vessel to reach CPA.

6.2 PLAN FORMAT

All Husky Oil contingency planning follows a standard format. This consistency allows any Husky Oil emergency response personnel to become quickly assimilated into an emergency response at any company facility. As a result, Husky Oil has the basis for continuous improvement of its corporate response capability and a complement of trained responders who can be employed as required in an emergency response at any company facility.

6.2.1 General Layout

The plan will be controlled in its distribution to company employees, contract personnel and regulatory agencies. Each copy will be numbered and assigned to a designated user. Each page is clearly labelled to indicate the revision date and chapter and page numbers. The plan will be produced in 8.5” x 11” format and bound in a 3-ring binder for ease in updating. The plan will be divided into logical sections and appendices separated by colour-coded tabs for quick access.

6.2.2 Division of Content

The content of the main portion of the plan will be based on a standard outline (Table 6.2-1). Procedures for specific emergencies will be presented in dedicated appendices.

Table 6.2-1 Overview Content for White Rose Project Contingency Plans

Section	Description
Introduction	C Purpose and scope of plan C Geographic coverage C Definition of emergencies covered
Action Plan	C Conditions leading to emergencies C Stages of alert and response C Roles and responsibilities C Notification procedures C Specific response activities
Emergency Telephone List	C Emergency services groups C Company personnel C Contractors and suppliers C Government contacts
Area Considerations	C Location maps C Facility and vessel diagrams C Sensitive areas near the emergency scene
Emergency Support	C Medical services C Logistics support resources C Media guidelines C Family support C Communication systems
Emergency Preparedness	C Plan maintenance C Personnel training C Exercises
External Assistance	C Mutual Aid arrangements C Canadian Coast Guard assistance C Well relief resources C C-NOPB Emergency Response Plan

6.3 CLASSIFICATION OF EMERGENCIES

The level of response to an emergency at White Rose will be dictated by the scale of the incident. Husky Oil uses a tiered approach to response (“principle of graduated response”) that relies upon increasing levels of resources from a larger pool as the scope of an emergency escalates. There are four stages of emergency in Husky Oil’s response process, including an alert stage which acknowledges threatening circumstances that may precede an actual emergency.

6.3.1 Alert Stage

An alert stage will be declared when any condition exists or is forecast which does not require immediate emergency response but has the likely potential to escalate into a defined emergency situation. Examples include forecast heavy weather or approaching icebergs that have the potential to become emergency situations.

6.3.2 Emergency Stages

6.3.2.1 Stage 1 Emergency

The Offshore Installation Manager (OIM) will declare a Stage 1 Emergency when a situation is confirmed that will affect one area of the site or facility. At this stage, there is no immediate hazard to the public or environment and there is no immediate danger of uncontrolled escalation.

The emergency may not be trivial and could include loss of life. The key feature of a Stage 1 Emergency is that the effect is limited and identified and that the conditions that led to declaration of an emergency have either passed or have been controlled so that no further escalation is anticipated.

Actions include internal and regulatory notification and response by on-scene personnel, with logistical support, as required, from shore. Until the emergency has been declared over, responders will take the necessary steps to prepare for a possible Stage 2 Emergency.

6.3.2.2 Stage 2 Emergency

In a Stage 2 Emergency, the related effect is broader than just a confined portion of the site or facility. The situation has the potential to result in serious off-site effects and there is some hazard to the public or the environment. A key feature is the potential for uncontrolled escalation.

Primary activities focus on ongoing response and containment. At Stage 2, additional personnel or equipment may be needed from shore or from other operators offshore, to support the on-site resources.

6.3.2.3 Stage 3 Emergency

A Stage 3 Emergency is considered to be a major emergency in which operating control has been lost and the integrity of the facility is threatened. The situation is escalating and uncontrolled and definite, and serious hazard to the public or environment exists.

The primary activities include ongoing response and containment, mobilization of external resources, and implementation of public information initiatives.

6.3.3 Post-Emergency Stages

Once the conditions that led to the emergency have passed, Husky Oil will take measures to terminate the response in an orderly and responsible fashion. Some of the actions that are prescribed during this stage of an emergency response will include:

- advise all company and contract personnel, government agencies, and the public of the termination of response operations;
- initiate incident debriefing, reporting, and investigation;
- ensure integrity of all equipment before returning to production operations;
- monitor needs for critical incident stress debriefing for response personnel;
- implement longer term effects monitoring program, if required;
- review response actions and modify ERP, as required; and
- complete all financial issues relating to the response.

6.4 EMERGENCY RESPONSE MANAGEMENT

6.4.1 Management System Processes

The White Rose emergency response structure will be based on the organization of action-oriented teams structured for the rapid and efficient response to emergencies. Organization will be specific to each operating location but within the context of a corporate system. Response organization will be comprised of four levels:

- Corporate Emergency Response Team (CERT);
- East Coast Emergency Response Team (ECERT);
- Offshore Emergency Response Team (OERT); and
- Offshore Emergency Action Teams (EAT) including
  - Technical Operations Team,
  - Medical Team,
  - Fire Team,
  - Helideck Team,
  - Lifeboat Team,
  - Fast Rescue Craft Team, and
  - Spill Response Team.

This structure relies on a strong response team offshore which is in command of trained action teams to implement specific actions. Offshore personnel will be supported and complemented by regional and corporate teams in the event that the incident escalates.

Management will rely upon close interaction between team members. As most decisions must be made quickly, management team members will work very closely together. All communications will be as efficient as possible. The focus at this stage will be directed towards dealing with the emergency.

Documentation will be efficient, relying on status boards and pre-formatted self-carbon note pads. Reporting will be done upon completion of the response and be based upon the documentation generated during the response by the responders themselves.

6.4.2 Response Organizational Structure

All emergencies covered by this plan will take place offshore at or near the White Rose production field. In most cases, regardless of the level of the emergency, the OIM on the FPSO or MODU will act as On-Scene Commander (OSC) and be in command and control of response operations. Exceptions would be:

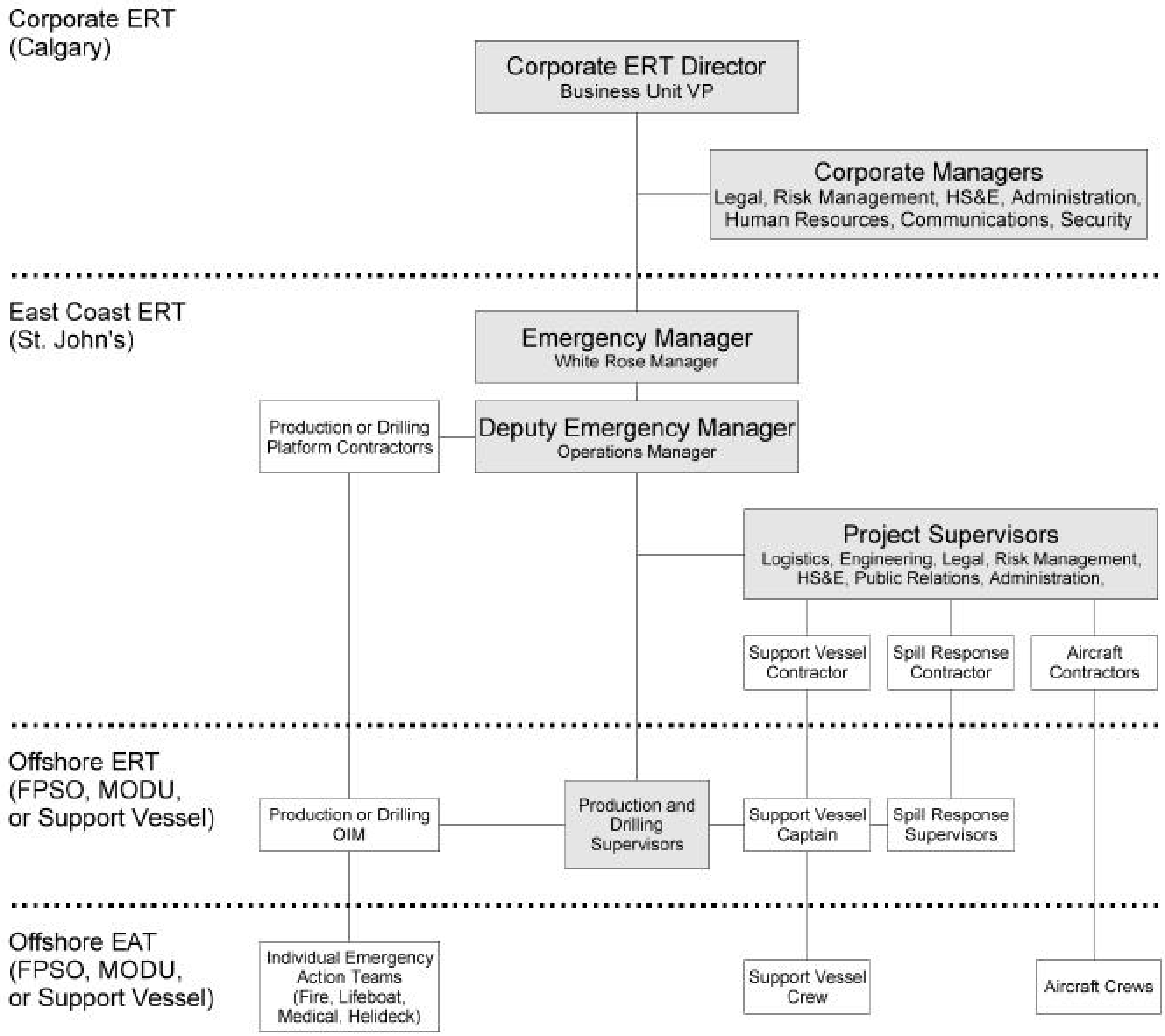
- loss of the FPSO or MODU (OSC would shift to another platform or standby vessel);
- Search and Rescue (SAR) Operations in which case RCC (RCN - Halifax) or MSRC (CCG - St. John's) will take command; and
- major oil spill, during which overall incident command will be based in St. John's.

Even in cases where command is not based offshore, the Offshore ERT will coordinate all offshore operations and be a principal point of contact for all other responders.

6.4.2.1 General Emergencies

The main role of the shore-based East Coast ERT (Figure 6.4-1) is to provide support for operations taking place offshore and for developing larger scale response plans. Support could be provided in a number of different ways, including logistics, materials, technical advice, regulatory liaison, family notification, and media or public relations. In major emergencies, support offered by the corporate ERT will generally consist of public relations, insurance issues, legal advice, risk assessment, and impacts to corporate business created by the emergency. In major emergencies, operational management will usually remain with the on-shore or off-shore ERTs.

Figure 6.4-1 General Organization For White Rose Emergency Response Management

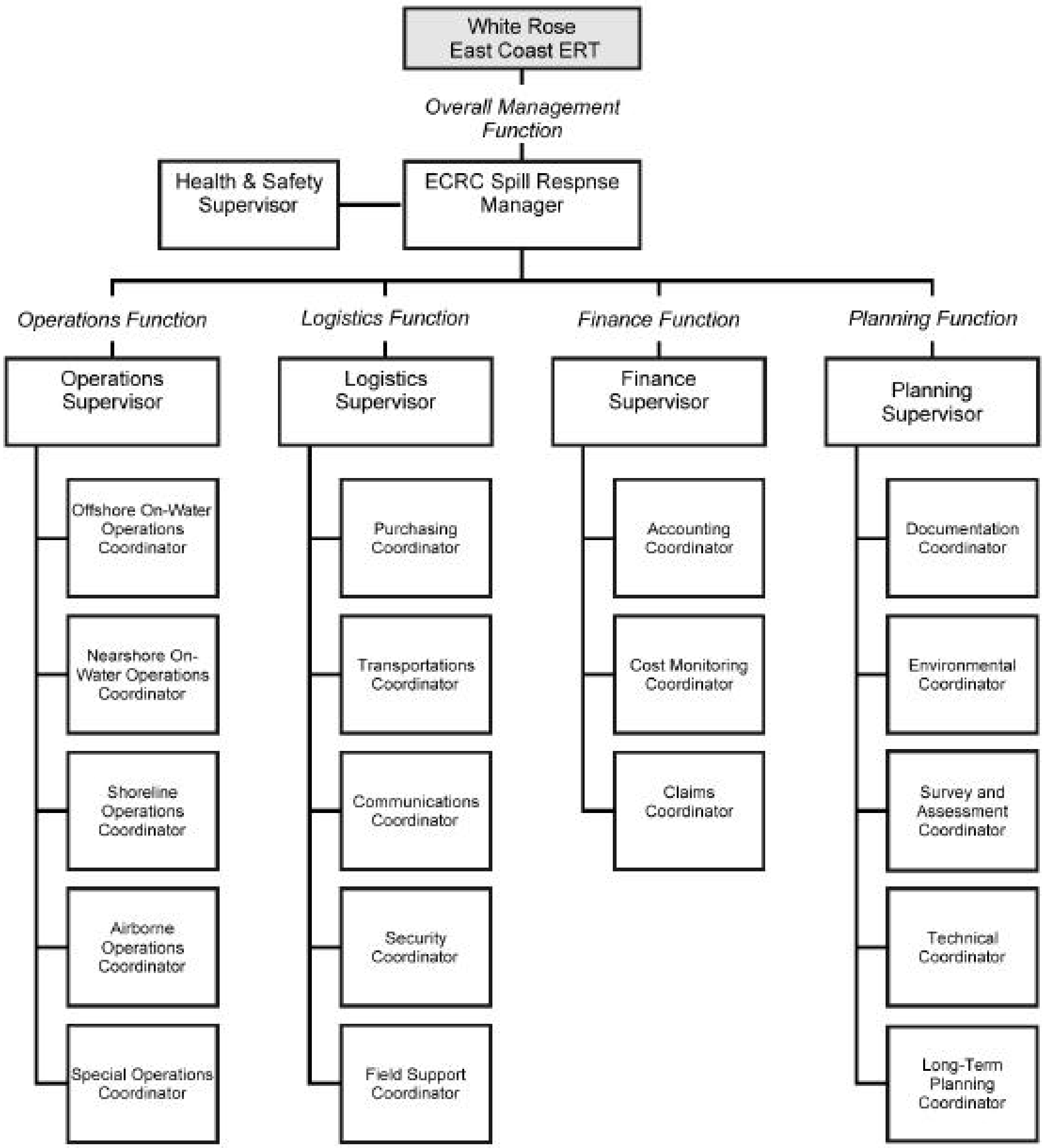


6.4.2.2 Oil Spill Response

In the event of a major oil spill, the operational component of the response will be managed by using a unified management approach such as the Incident Command System (ICS). The ICS emergency response management structure has been widely adopted by emergency response agencies throughout North America as a means of sustaining a long term response effort by adopting a function-based approach that allows personnel to rotate through positions over an extended period.

The Eastern Canada Response Corporation (ECRC) Spill Management System is ICS-based. Hibernia Management and Development Company (HMDC) and Terra Nova are also developing ICS-based oil spill response procedures. The fully activated ECRC ICS management structure is outlined here in Figure 6.4-2.

Figure 6.4-2 ECRC Incident Command System-Based Oil Spill Response Management Structure (Expanded for major oil spill)



6.4.3 Response Centres

An Offshore On-Scene Command Post will be staffed on the FPSO or MODU within minutes of the declaration of an emergency. This site will be the headquarters for the Offshore ERT and all off-platform communications. This centre will be supported by the Central Control Room, which will be the primary point of contact for all personnel on the platform. In the event the platform must be abandoned, the command post will shift to the remaining platform or, if necessary, to the standby vessel.

On-shore emergency response activities will be directed from an Emergency Response Centre within the Husky Oil office in St. John's. This site will be staffed by the East Coast ERT. Depending upon the circumstances of the emergency, the Emergency Response Centre will be supported by a Media Centre and Public Inquiry Centre (family support centres). In the case where the emergency is a major oil spill, the Emergency Response Centre will be supported by a dedicated Oil Spill Response Centre.

Oil spill response operations will be managed on shore from a dedicated Response Centre shared with Terra Nova and HMDC and located at Pier 12 in St. John's. The Response Centre will be kept in a state of readiness at all times and be outfitted with complete telephone, fax, and data communications and all spill management maps and posters. All reference and reporting materials will be available at the Response Centre. All spill response training and exercise practices for company and contract personnel will take place in the Response Centre.

6.4.4 Use of Response Contractors

In general, White Rose emergency response management personnel will be drawn from in-house resources and include both Husky Oil and major contractor staff. In the event of an oil spill, however, the incident may require considerable resources over an extended period. In such a case, it will be necessary to use the services of additional personnel to assist in the coordination of response operations. In such a case, Husky Oil would use ECRC in a spill response management role. ECRC could be used in one of two ways:

- ECRC could act as a stand-alone response management entity answering to the East Coast ERT. In this case, ECRC personnel would probably be based at its Mount Pearl response depot; or
- Husky Oil and ECRC personnel could be integrated into a single team working from the Husky Oil Response Centre. Common grounding between the Husky Oil spill response plan and ECRC in ICS management will allow for such an integration to be efficient.

Depending on the scope and type of incident, additional resources from experienced contractors would also be mobilized.

6.5 ROLES AND RESPONSIBILITIES

6.5.1 Roles During an Oil Spill Incident

The response management structure used by Husky Oil during an oil spill incident defines the functional roles for all supervisory personnel. These functions include Command, Operations, Planning, Logistics, and Finance. Additional functions that might be required as the scale of the emergency escalates are shown in Figure 6.4-2. The specific tasks that individuals will be assigned will be determined over time as a result of the evolution of the incident and consultation between functional groups. The Unified Management Approach process ensures that the level of response is always reasonable and necessary through:

- established and communicated objectives;
- integrated field operations, tactical planning, and logistics support through situation analysis;
- longer term planning and operational preparation based on prediction of future situations; and
- information exchange through continuous interaction of supervisory personnel, scheduled review meetings, routine written reports, and daily proposed action plans.

6.5.2 Roles During Non-Oil Spill Incidents

In all other emergencies, which are generally short term by nature, the emphasis will be more on rapid response to very specific scenarios. In many cases, the conditions of the emergency can be anticipated so that action plans can be prepared in advance. General responsibilities for White Rose emergency response personnel in non-oil spill incidents are shown in Table 6.5-1. More detailed versions of this table and specific task summaries for individual team members will be developed in specific plans.

Table 6.5-1 General Response Actions for Non Oil Spill Incidents

Level	Corporate ERT	On-shore ERT	Offshore ERT (OIM)
Alert	– No formal notification	– Notified by OIM – Alert ERT, review actions	– Notify On-shore ERT, vessels – Alert ERT, review actions
Stage 1	– Notified by On-shore ERT	– Support field operations – Identify potential technical resources – Maintain contact with OIM, and other operators – Media and Public Relations	– Control field operations – Notify First Response regulators – Use platform resources – Maintain contact with On-shore ERT, vessels, and other platforms
Stage 2	– Maintain contact with On-shore ERT – Mobilize Corporate Emergency Response Team (CERT), review actions	– Coordinate overall response – Plan large scale response ops. – Support field operations – Maintain contact with OIM, CERT, regulators, and other operators – Media and Public Relations	– Control field operations – Request shore resources – Maintain contact with On-shore ERT, vessels, and other platforms
Stage 3	– Manage corporate position – Direct corporate aspects of response – Media and Public Relations	– Coordinate overall response – Plan large scale response operations – Support field ops. – Maintain contact with OIM, CERT, regulators, and other operators. – Family support. – Local media and public relations.	– Control field operations – Request shore resources – Maintain contact with On-shore ERT, vessels, and other platforms

6.6 NOTIFICATION AND DOCUMENTATION

6.6.1 Notification

Once an emergency has been declared, timely notification of associated persons or agencies will be critical. In some cases, notification may include a written report (Section 6.6.2).

Contingency plans will include instructions for all personnel who have a notification responsibility. Initial notifications will be submitted by the Offshore ERT under the direction of the OIM. Where appropriate and convenient, further notifications may be delegated to shore personnel. All other notification actions will be included in the specific role descriptions of each response team member and will be summarized in an overall notification checklist.

6.6.2 Emergency Notification and Log Forms

All personnel will be required to keep an accurate record of events and actions in which they are personally involved. Good documentation will assist in describing the situation at any time, as well as recording events for incident reporting.

To ensure efficiency and accuracy of reporting, standard forms will be used wherever practical. Following is a list of forms that will be used:

- Initial Incident Report, which:
  - includes critical incident information for general distribution,
  - is completed by the Offshore ERT, and
  - includes Standard IMO format for vessel information;
- Initial Briefing Report, which:
  - includes detailed incident information, and
  - is for use of ERT personnel;
- Action Log, which:
  - documents specific actions, and
  - includes a personal log;
- Resources Summary, which:
  - includes current status of all vessels, equipment, and personnel involved in response;
- Daily Situation Report, which:
  - including detailed summary of the day's activities,
  - makes recommendations for next day's work, and
  - is for use of ERT and senior management personnel; and
- Bomb/Terrorism Threat Forms, which:
  - includes a report form for recording content of threatening communications, and
  - provides guidelines for personnel inexperienced in security issues.

6.7 EMERGENCY PREPAREDNESS

6.7.1 Plan Distribution

Contingency plan distribution will be carefully controlled. Personnel on the distribution list will include ERT members, C-NOPB, FPSO and MODU owners' representatives, standby vessels, St. John's shorebase, and Canadian Coast Guard (Search and Rescue) as well as other agencies such as RNC, RCMP, DFO and EC. Each plan copy will be identified by a unique code assigned to the plan holder.

6.7.2 Plan Maintenance

White Rose contingency plans will be dynamic documents which must be updated as needed to reflect changes in project operations. So that the version of any part of the plan can be identified, plans will be assembled in three-ring binders and each page will be clearly labelled with document identification code, plan version reference, and date that page was generated. Updates will be issued as they are produced to designated plan holders. Upon receipt of updates, plan holders will insert replacement pages and destroy those pages which have been replaced.

6.7.3 Personnel Training

All regular East Coast operations personnel, including contractors, will receive directed emergency training. External personnel who play some role in White Rose emergency operations will be provided with a general orientation and a specific review of personal roles.

Training will be conducted according to a matrix that links personnel positions with types and levels of training required for each position. Levels of training required for specific ERT and EAT personnel will range from basic awareness of an activity or function to achieving a working knowledge to becoming an expert in that function. In some cases, personnel will be required to be certified for certain activities. Wherever possible, training will be conducted to recognized standards and certified instructors will be used. A schedule for refreshers, retraining, and re-certification will be established for all plans.

All personnel will undergo an orientation to elements of emergency response planning. Offshore personnel will receive a general overview of evacuation alarms and procedures, and response organization. To ensure familiarity with emergency response planning, a portion of all HS&E meetings will be devoted to emergency response issues.

EATs will receive specialized training with emphasis on hands on experience. Emergency drills will be conducted weekly, bi-weekly, or monthly for all EAT activities.

6.7.4 Response Exercises

A regular program of exercises will be instituted to ensure the readiness of all personnel. The frequency of exercising will vary with each task but will be no less than annual. The purposes of exercises include:

- continuing training and familiarization of all personnel with emergency procedures;
- testing of the preparedness of all personnel; and
- a means of developing continued improvement to emergency procedures.

Exercises will be conducted in three areas:

- Communications, which includes
  - personnel call out,
  - inter-facility communications testing, and
  - media and public information training;
- Table Top, which includes
  - methodical response to an emergency scenario by the on-shore and/or offshore ERT, and
  - an opportunity for interaction between ERT, operational, regulatory, and external personnel; and
- Logistics, which includes
  - hands-on training and experience for marine and technical personnel.
  - demonstration of field response operations for marine crews, ERT, other operators' personnel, and regulators, and
  - confirmation of the effectiveness of established field procedures.

6.8 MUTUAL AID AND INTEGRATION WITH OTHER OPERATORS' PLANS

Husky Oil has entered into a formal mutual aid agreement with other Grand Banks operators. This agreement provides for the release of personnel, vessels, and equipment for logistics support and exchange of operational information. Under this agreement, operators are required to provide support if requested by a second mutual aid operator. The level of this support is limited to that effort that can be provided without jeopardizing the safe operation of the supporting operator's facilities. Mutual aid will be most evident in logistics issues, ice management, and oil spill response efforts.

So that mutual aid may be effective, the mechanism for interaction between operators will be clearly stated in all White Rose contingency plans and other operators will be provided with controlled copies of appropriate plans.

6.8.1 Logistics

Other offshore platforms may be used to provide nearby staging or refuelling platforms in support of a Husky Oil emergency. These platforms may also provide temporary accommodation for evacuated platform personnel.

Several logistics services are currently shared by all operators. Cougar Helicopters has been contracted by all operators to provide helicopter transportation services to offshore facilities. Stratos Communications provides flight following and fleet tracking services as well as shorebased radio communications support to all Grand Banks operators. Vessel management, while not completely integrated between all operators, can be quickly coordinated through interaction between company and vessel owner's logistics personnel.

6.8.2 Ice Management

Ice data collected by all operators will be shared and efforts to manage oncoming icebergs will be taken with the advice and knowledge of neighbouring offshore facilities. All operators have currently contracted PAL for airborne surveillance activities. All PAL, CIS, and IIP ice data are integrated and readily available to all operators. When combined with site-specific information provided by individual operators, all operators have the benefit of complete and timely reports of ice conditions. Integrating between all Grand Banks operator's ice management plans is discussed in more detail in Section 2.5.4.

6.8.3 Oil Spill Response

In the event of a major offshore oil spill, countermeasures equipment will be available at each permanent production platform. As well, all operators have access to a dedicated oil spill response centre at Pier 12 on St. John's Harbour. This facility is permanently equipped with the resources to manage an offshore oil spill response. The layout and materials in this centre are geared to an ICS management effort, in keeping with the spill response plans of all operators, ECRC, and Canadian Coast Guard.

6.9 RESPONSE CONTRACTORS AND OUTSIDE AGENCIES

Depending upon the nature of the emergency, Husky Oil will work closely with a variety of external agencies who will participate actively in the response action. The roles and means of interaction for each of these groups or agencies will be clearly indicated in the appropriate plan. External agencies will be provided with controlled copies of the plan to ensure that cooperation with Husky Oil is efficient.

6.9.1 Regional Environmental Emergency Team

The Regional Environmental Emergency Team (REET) is a group of environmental specialists chaired by EC who can provide knowledgeable advice to support response operations. In the event of a spill, REET may be activated either by C-NOPB or EC.

Most REET members are government (federal and provincial) representatives from the local area. Private sector personnel may also be included in REET. EC may choose to draw on regional or national expertise, as required, to provide the best possible advice. Some REET members also have regulatory responsibilities and may be the best contact for permits for operational activities.

6.9.2 Rescue Coordination Centre/Marine Rescue Sub Centre

The federal government has the responsibility for coordinating all Search and Rescue (SAR) activities in Canada. The Department of National Defence (DND) is responsible for aeronautical operations and the coordination of air and maritime SAR coordination. The Canadian Coast Guard is responsible for maritime operations. The Halifax Rescue Coordination Centre (RCC), staffed by DND personnel, is tasked with coordinating all SAR activities in the Atlantic Canada Search and Rescue Region (SRR). The Marine Rescue Sub Centre (MRSC) in St. John's is staffed by Canadian Coast Guard personnel and is responsible for direct coordination of maritime SAR actions in Newfoundland waters.

The SAR Coordinator at either RCC or MSRC will be in command and control of all SAR actions. Where appropriate, the White Rose OIM may act as an at-site coordinator of local operations. All Husky Oil offshore installations and support vessels will be equipped with the IMO SAR Manual and the Merchantship SAR Manual. Husky Oil will immediately contact RCC and MSRC in any emergency involving:

- call to muster stations;
- fire or explosion;
- person overboard;
- structure damage;
- vessel collision; and
- all aircraft or marine incidents at or near the White Rose site.

6.9.3 Police

White Rose emergency planning will incorporate the support and responsibilities of police services. The Royal Newfoundland Constabulary (RNC) will provide local services in the City of St. John's and the Royal Canadian Mounted Police (RCMP) will be responsible for offshore incidents.

6.9.3.1 Royal Newfoundland Constabulary

As well as its responsibility for investigating incidents within its own jurisdiction (northeast Avalon area), the RNC will assist in interactions with local fire, ambulance and hospital services. The RNC also plays a large role locally in the notification of next of kin as part of the Family Support Plan and assists in access control.

6.9.3.2 Royal Canadian Mounted Police

The RCMP will be responsible for any offshore incident requiring police involvement. Some of the incidents that will require the RCMP include:

- major injury or loss of life;
- bomb threat; or
- aggressive or threatening behaviour.

6.9.4 East Coast Response Corporation

Husky Oil has a subscriber's agreement in place with East Coast Response Corporation (ECRC) for the provision of operational and management services in the event of a major oil spill. ECRC is a full-time oil spill Response Organization certified by Canadian Coast Guard under Chapter 36 of the *Canada Shipping Act*. This contract allows Husky Oil to access ECRC personnel and equipment at any time.

Husky Oil intends to contract ECRC to carry out the routine management of a Stage 2 or Stage 3 oil spill response. By incorporating ECRC's existing Spill Management Team into the White Rose response structure, much of the administrative and planning work can be delegated to qualified contract personnel, thereby ensuring continuous availability of trained personnel reducing the work load of Husky Oil personnel.

In assuming an operational management role, ECRC will work under the direction of Husky Oil. ECRC will manage the response and be responsible for developing tactical and strategic plans for spill response operations. All plans will be reviewed and authorized by the White Rose Incident Commander prior to implementation.

6.9.5 Canadian Coast Guard

The Canadian Coast Guard maintains an operational spill response staff as well as a large inventory of oil spill response equipment at its depot in Mount Pearl. As well, the Canadian Coast Guard operates a fleet of vessels suitable for offshore oil spill response activities. In the event of a major oil spill event, Husky Oil will contract Canadian Coast Guard resources as required to bolster industry and ECRC resources. Recent oil spill exercises have included practising the integration of Operator, Coast Guard and ECRC resource to enhance preparedness for a major spill.

6.9.6 Relief Well Considerations

In the event of a wellsite loss control emergency, it may be necessary to drill a relief well. If a White Rose MODU is not on site or unable to do this, an alternate drilling vessel would be required. Throughout the lifetime of the White Rose production program, Husky Oil will maintain a listing of drilling vessels that could be brought to White Rose at short notice to drill the relief well.

6.10 OIL SPILL RESPONSE

Oil spill prevention will be incorporated into the day-to-day operations of the White Rose production project. All offshore systems and structures, procedures, and programs will be designed with due regard for the prevention of loss of any hydrocarbons. At the same time, Husky Oil will undertake all the necessary planning, training, and exercising to ensure that the appropriate spill response capability is in place for all phases of the White Rose project.

6.10.1 Oil Spill Prevention

Standard operating procedures to reduce or eliminate the chance of a spill, even in the case of equipment failure, will be instituted for all oil handling operations. Routine maintenance and testing schedules will be established for all aspects of the production program, with particular attention paid to well control, product storage and handling, and fuel transfer systems. Prior to production, practices for operating in poor weather, high seas, sea ice, and iceberg conditions will be established. Good communications and sound marine practices for all vessels will also improve the ability to prevent spills.

To promote proper environmental operating practices, regular inspections and audits of the offshore platform will be performed. The general awareness of offshore workers will be increased through training, seminars, and safety meetings. Personnel will be encouraged to report potential problems and 'near miss' incidents in an attempt to avoid a re-occurrence that could result in a loss of containment or other release/discharge of oil.

6.10.2 Oil Spill Response Management

Oil spill clean up operations will be managed as a special emergency response action as described previously in this document. The key features to White Rose oil spill management will be:

- Stage 1 incidents will be managed by the Offshore ERT using equipment, vessels and personnel at site;
- Stage 2 and Stage 3 incidents may require equipment and management support from shore and will involve Husky Oil East Coast ERT then Corporate ERT;
- Ongoing Shore-based Stage 2 and Stage 3 incident management activities will take place at the Oil Spill Response Centre;
- ECRC will assist Husky Oil in managing the operational aspects of a Stage 2 or Stage 3 spill response; and
- Oil Spill Response management system will be compatible with the ICS.

6.10.3 Background Considerations to Oil Spill Response

6.10.3.1 Assessment of Spill Risk

In Chapter 5, the risks of various levels of oil spill have been assessed based on world-wide historical statistics. Clearly, the probability of smaller spills, especially involving fuel or crude transfers, is much higher than for large and very large spills (see Table 5.6-1). Even though the probability of a major spill is expected to be very low, Husky Oil will, nevertheless, prepare for such an incident in the White Rose Oil Spill Response Plan. Planning standards which detail the amount of oil spilled and operating conditions at the time of the spill will allow Husky Oil to ensure that the level of effort is adequate for any planning scenario.

Based on forecast drilling and production activities, several potential spill scenarios can be considered (Table 6.10-1).

Table 6.10-1 White Rose Potential Oil Spill Scenarios

Spill Source / Description	Scale of Spill	Type
Blowout		
Uncontrolled flow of gas, oil, or other well fluids from the reservoir (subsea or at the surface) during drilling, completion, or workover.	• Actual flow based on well pressure. • Duration dependent on stability of uncased well bore.	Crude Oil
Batch Spills		
Platform Process Equipment Failure Process upset, control failure, or rupture of process piping, equipment.	• Small amounts, low risk of release to environment.	Crude Oil
Storage Cell Rupture Rupture of crude oil storage cells in FPSO or tanker.	• Worst Case: 30,000 m^3- 24 hrs (rapid loss of FPSO containment).	Crude Oil
Pipeline Rupture/Loading System Failure Rupture of pipeline(s) to FPSO or loss of connection with tanker while loading crude oil.	• Volume depends on sub-sea pump rate, duration of pumping after rupture is identified, and volume of oil in OLS pipeline.	Crude Oil
Diesel Fuel Transfer Failure of off-loading line or connection with Multifunctional Platform Support vessel while transferring diesel to platform.	• Low volume, limited persistence.	Diesel Oil

6.10.3.2 Anticipated Fate of Spilled White Rose Crude Oil

Recent preliminary testing of White Rose crude oil indicates that the following features must be considered when making decisions concerning oil spill response options:

- the crude oil may gel on contact with water due to high pourpoint of oil;
- when poured on water, the crude will create a highly viscous emulsion;
- sheen is expected to be minimal;
- waxiness will limit evaporation; and
- when crude is sprayed, its waxiness will create small droplets that will not break down or emulsify quickly. Floating oil will form mats (not slicks) which will be persistent and interspersed with areas where there is no oil.

6.10.3.3 Fate of Diesel Oil Spilled at White Rose

Diesel oil may be spilled at White Rose during the transfer of fuel from a support vessel. Characteristics of diesel oil spilled in Grand Banks conditions include:

- will spread quickly creating considerable sheen;
- a large part of the low molecular weight components will evaporate;
- residue will weather and become more viscous;
- threat to seabirds when fresh or weathered; and
- when spilled in large volumes, diesel may have toxic effects on fish, plankton, and epibenthic and benthic communities.

6.10.3.4 Fate of Other Products Spilled at White Rose

Other oily substances that could be spilled at the White Rose field include hydraulic oils, mechanical lubricants, and drilling fluids. Some of the characteristics of these substances that should be considered in a spill response include:

- they will spread quickly, considerable sheen;
- the residue will weather and become more viscous; and
- they may be a threat to seabirds when fresh or weathered.

6.10.3.5 Predicted Spill Trajectories

The predictions of the fate of oil spilled at the White Rose location based on local current and historical wind conditions showed that almost no conditions experienced in the past would create a situation where oil spilled at the White Rose site would be transported to the island of Newfoundland. A total of 14,600 trajectories were modelled in this analysis. It was found that there were no shoreline contacts from any of the spill trajectories originating at the White Rose site. A more detailed discussion of oil spill trajectories is given in Section 5.8.5.3.

6.10.3.6 Resources at Risk

Biological resources on the Grand Banks can be found at three levels of the water column. At the surface, species immediately at risk include sea birds and marine mammals.

Risk of an ecological effect will depend upon the spatial and temporal distribution of resources and the probability of the spilled oil reaching the location and depth of the resource at the time of the spill. The effects of an oil spill on the biota are discussed in detail in Section 5.9.

6.10.4 Oil Spill Strategies and Procedures

6.10.4.1 Response Options

At the time of an oil spill, a response strategy must be developed quickly. While every spill response will be unique, there are only a few basic strategies that can be practically considered. The response options available during an offshore spill are listed in Table 6.10-2.

6.10.4.2 Oil Spill Response Capabilities

Husky Oil's capability to respond to an oil spill at White Rose will include:

- a first response capability based at the White Rose site;
- the first response equipment kept at other Grand Banks drilling and production platforms;
- White Rose support vessels, other operators vessels, Canadian Coast Guard vessels, and other charter vessels;
- ECRC operational spill management services provided on contract to White Rose;
- ECRC personnel and equipment provided on contract to White Rose;
- Canadian Coast Guard Environmental Response personnel and equipment for larger spill response operations provided on contract to White Rose; and
- access to Oil Spill Response Limited (OSRL), which will provide access to a large amount of equipment and trained personnel in the event of a very large spill event.

Table 6.10-2 Potential Response Options at White Rose

Response Option	Comment
Natural dispersion and degradation	• Oil is broken into small droplets then naturally metabolized by micro-organisms • Effectiveness improves as wind and seastate conditions deteriorate • Only option in poor conditions
Surveillance and monitoring	• Necessary for all spills • Good Grand Banks capability • More difficult in darkness or low visibility • Monitoring may be the only response option available in poor conditions
Mechanical dispersion	• Good for small spills – quick implementation, use of ship's propulsion system to disperse floating oil
Containment and recovery	• Effective but limited by seastate and by need for high logistics support • Low recovery rates as slick spreads
Chemical dispersion	• Quick application over large areas with modest logistics support • Effectiveness depends upon oil characteristics • Regulatory permitting required because of concerns for introducing chemical to the marine environment
insitu burning	• Oil can be burned in large volumes, if thick • Specialized boom required • Logistic requirements to gather oil prior to burning are considerable • May be very useful in a very large spill or in pack ice conditions
Wildlife measures	• Surveillance to determine distribution of wildlife and potential for effects • Techniques for deterring wildlife are limited

6.10.4.3 Strategies

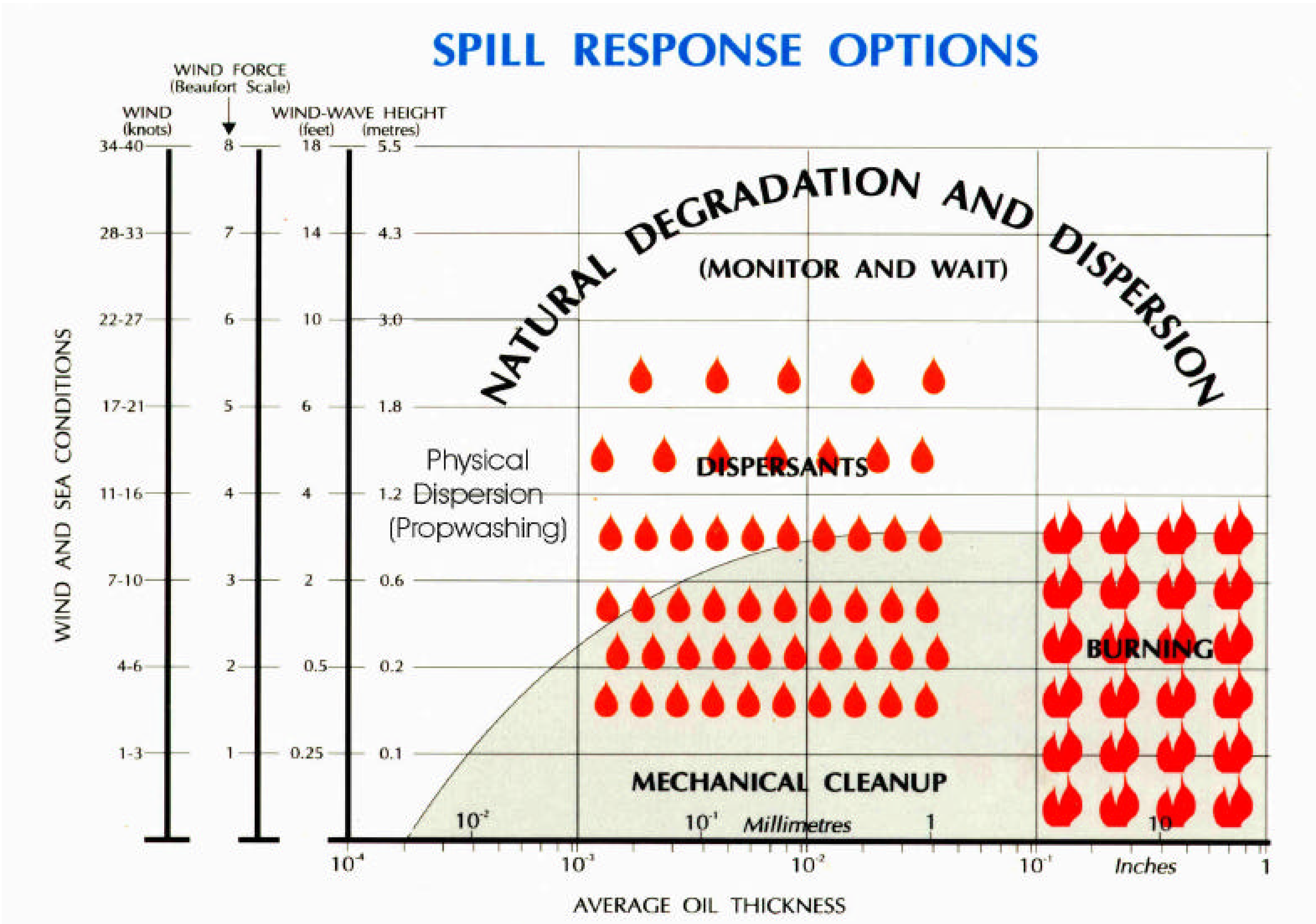
The actual strategy developed for any incident will be based on:

- the nature of the oil that might be spilled;
- operating conditions at the time of a spill;
- logistics considerations;
- the current availability of equipment;
- existing contract services and provisions available from other offshore operators; and
- the requirements of C-NOPB and other regulatory agencies.

Approximate operating windows for specific techniques are shown in Figure 6.10-1. There is considerable overlap in the abilities of each technique to handle spilled oil and so, for any scenario, there is not always a prescribed strategy. Guidelines to be followed when developing a strategy include:

- safety is foremost; the On-Scene Commander will always make the most informed decision. When weather conditions are poor, natural degradation and dispersion are enhanced;
- if there are birds nearby, the use of physical or chemical dispersion should be considered to remove the oil from the sea surface; dispersant use must be authorized by C-NOPB;

Figure 6.10-1 Operating Windows for Spill Response Options



(Ref OSRL Handbook)

- propwashing (physical dispersion) is the best solution for sheen;
- sorbent boom should be considered for any small spill because of the speed of deployment and effectiveness of recovering;
- every planned task should include frequent situation analysis to determine the success of the operation. Regular re-evaluation will help the On-Scene Commander to decide when to terminate operations;
- aerial surveillance is required. Use any aircraft (including DFO fisheries or Canadian Coast Guard pollution flights) working in the area at the time of the spill. If the volume of oil spilled is unknown or if conditions are hard to control, arrangements should be made for dedicated aerial reconnaissance; and
- waste disposal will be a problem in every spill response and could create bottlenecks in operations (joint industry oil spill exercise in September 2000 practiced strategies to address this potential).

6.10.4.4 Response Methods

Situation Analysis and Information Gathering

An offshore spill is likely to spread quickly and break up in poor weather conditions. Countermeasure operations away from the spill source will be successful only if accurate and up-to-date information on the oil's properties and behaviour, slick sizes, and projected movement are known. Updated slick information for a White Rose oil spill will be obtained through continuing marine observations by all response vessels and airborne surveillance activities by company helicopter and fixed-wing aircraft contractors.

Current and forecast weather conditions will be provided by existing White Rose operations. Trajectory models based on best possible environmental conditions and a knowledge of the weathering characteristics of the oil will assist response planners in directing field operations.

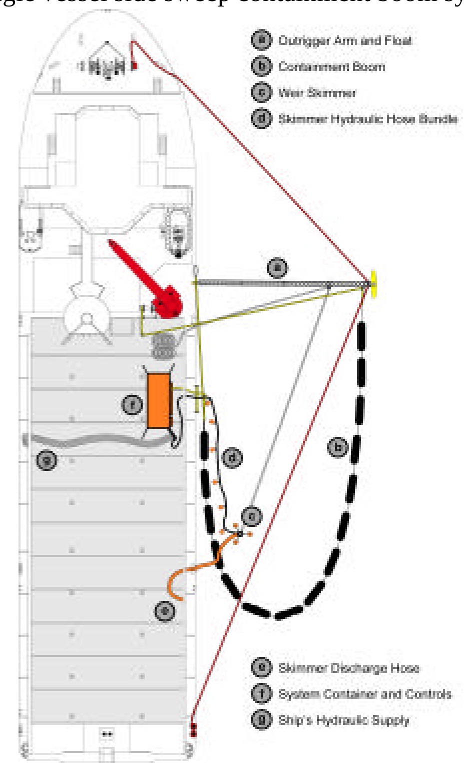
Containment and Recovery

Floating oil can be contained by towed floating booms. Three boom configurations used commonly on the Grand Banks are shown in Figure 6.10-2. Booms may be configured to be towed from an outrigger arm mounted on a single vessel or in a longer form towed jointly by two vessels.

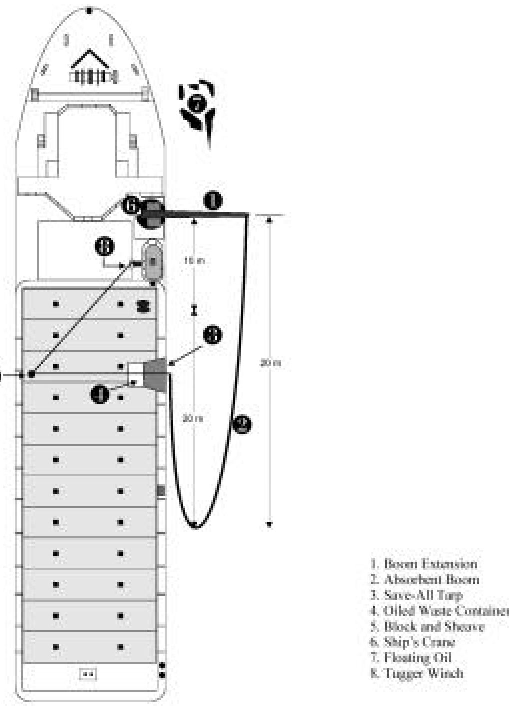
Conventional booms are constructed so that a buoyant upper section supports the boom and acts as a barrier to splash over of contained oil and a sinking skirt acts as a barrier to oil that might be entrained under the boom. In offshore conditions, the seastate in which the boom can be used is limited by its own dimensions. Because of its large horizontal and vertical profile, the boom must be towed slowly to avoid both splash over and entrainment. Oil is recovered from the apex of the towed conventional boom by means of a floating skimmer pump system that separates floating oil from the seas surface underneath before discharge to storage tanks on board the recovery vessel.

Figure 6.10-2 Three Offshore Oil Spill Boom Systems

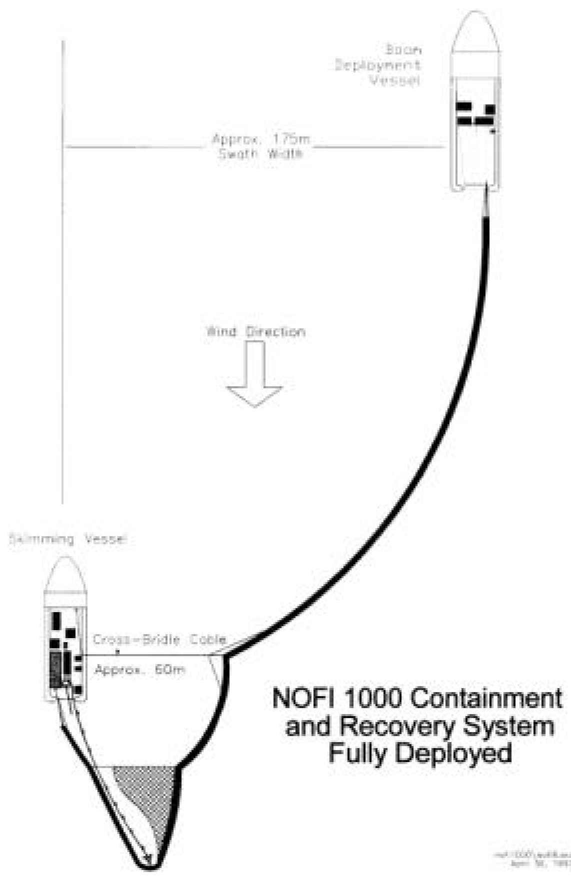
Single vessel side sweep containment boom system



Single vessel Sorbent boom recovery system



Two vessel containment boom system



Recently, Husky Oil has had success in small spill clean up using sorbent boom systems. These booms are assembled from sections of cylindrical sorbent material that collects oil but not water. It can be deployed quickly by the standby vessel. The boom both collects and recovers oil by skimming the surface. Although the sorbent material is not very strong, there is very little drag in this system when towed due to the lack of a high out-of-water barrier and sinking skirt. Because the floating oil adheres to the sorbent material and a skimmer is not required, splash over is not problematic.

Dispersion

Dispersion is a natural process in any oil spill. Eventually, oil on water will be broken into small droplets through physical action and become available to bacteria for natural biological breakdown.

Intentional dispersion of oil can be a quick disposal option for offshore spills. This is usually accomplished through the application of chemicals using aircraft or vessel-based spray equipment. With prior authorization from EC, Corexit 9500, a chemical agent that may be considered for dispersion of surface oil is considerably less toxic than earlier chemical dispersants. Chemical dispersion may present a hazard to fisheries and the subsurface ecosystem, the dispersion of oil removes a very real threat to seabirds on the surface. In the description of oil weathering, it has been concluded that dispersants will only be effective while the viscosity of the spilled White Rose oil is low, shortly after release and before weathering or emulsification.

In Canada, the use of dispersants in a marine oil spill is strictly controlled by EC. In developing the Oil Spill Response Plan, Husky Oil will ensure that the weathering characteristics of White Rose crude oil are well-understood and will discuss the implications of using chemical dispersants with regulatory agencies. In the contingency plan, the decision-making process for the use of chemical dispersants would include operational and environmental considerations. The application of chemicals will be considered only if the probability of successful dispersion is high, if the benefits of removing oil from the sea surface are clear, and if the possible effect to the subsurface marine environment is acceptable.

Emulsion Breaking

White Rose crude is expected to be difficult to handle when emulsified, as it becomes very viscous and persistent. Emulsified oil has a very high water content, making transfer and storage inefficient. Finally, emulsified oil is resistant to *insitu* burning and both natural and chemically-induced dispersion. A possible solution to these problems is the application of emulsion-breaking chemicals. Considerations in the decision to include emulsion-breaking chemicals in the White Rose response strategy will include the high cost of maintaining an inventory and application techniques. In developing the Oil Spill Response Plan, Husky Oil will discuss the implications of using emulsion-breaking chemicals with regulatory agencies.

Insitu Burning

Combustion of oil on the sea surface has been proven effective in the Newfoundland Offshore Burn Experiment (NOBE) undertaken by EC and the Canadian Coast Guard during August 1993 (Fingas et. al. 1994). A safe and reliable helicopter oil slick igniter has been developed. Due to the limited operational life of a fire-boom and the logistics required to collect enough oil to burn, the use of *insitu* burning will be limited unless methods of burning without a fire-boom can be developed. Taking advantage of thickened weathered oil in naturally-formed windrows is one possible method that may have a potential future application. Oil that accumulates in pack ice leads may also be suitable for *insitu* burning.

6.10.4.5 Logistics Considerations

The White Rose logistics infrastructure will be employed to obtain materials specified by response managers, to transport operations personnel and equipment to and from the spill site, and to source additional operational platforms required.

One of the primary difficulties in mounting a large-scale offshore spill response operation will be to source the necessary vessels that will be used in the deployment of on-water equipment. The type of vessel most suitable for this application is the standard offshore supply vessel, which will be used to support the White Rose project offshore. At the present time, there are no surplus supply vessels available in Newfoundland and only a few available in Atlantic Canada. In a large-scale spill response, the number of local vessels available may be insufficient and outside vessels may be needed. In anticipation of this situation, Husky Oil will maintain a list of vessels that are available at short notice that may be useful for spill operations. This list will be complemented by the vessel of opportunity listing regularly-updated by ECRC.

The difficulty of coordinating a fleet of opportunistic vessels will be considered. Where possible, a vessel of opportunity will be used as a subordinate to an oil industry supply vessel in any two-boat operation.

Coast Guard Vessels

Canadian Coast Guard vessels *Sir Wilfred Grenfell*, *Sir Humphrey Gilbert*, *J.E.Bernier*, and *Ann Harvey* have been already designated for use with specific oil spill response equipment. *Teleost* and *Wilfred Templeman* may also be considered for towing the lead end of a J-configuration boom system. All Canadian Coast Guard vessels, especially buoy tenders will be less capable than industry ships in terms of seakeeping and waste oil storage. Although Canadian Coast Guard vessels are available to industry on charter, they may be obliged to discontinue spill response operations if a higher priority public emergency arises.

Vessels of Opportunity

Smaller, less specialized vessels may be capable of assisting in offshore spill response operations. A good choice of vessel type for the lead vessel role (towing the leading end of the guide boom) would be the conventional offshore stern trawler. These vessels are powerful and made for towing gear in difficult offshore conditions. Unfortunately, with the decline of the offshore fishery, they are not so readily available in Canada. The current offshore fishery is conducted by a Canadian fleet of 20-m (65-foot) longliners. These vessels are technically capable of handling the gear in question in sheltered waters but would probably be vulnerable in offshore conditions. Careful consideration must also be given to the cost of restoring a fishing vessel to its original condition after an oil spill response.

6.10.4.6 Equipment Requirements

Even with ongoing improvements, offshore collection and recovery equipment is still limited by seastate and would be suitable for use in Grand Banks conditions for a small proportion of the year. TFOSP estimated the proportion of time that countermeasures actions can be attempted on the Grand Banks to be approximately 5 percent of the time in winter and 25 percent in summer (TFOSP 1989). In the Terra Nova EIS (Petro-Canada 1995), these estimates were revised slightly to 3 percent in winter and 20 percent in summer. It should be noted that the period of the year during which equipment cannot be used coincides with the period of lowest biological activity. When conditions exceed the limits of on-water equipment, the potential for natural dispersion and recovery is greatest.

Boom Types

Most offshore booms (see Table 6.10-3) are curtain, pressure-inflatable booms. These booms all feature pressure-inflated air floatation chambers and underwater skirts (curtain). The underwater skirt may be ballasted with chain or use a second water-filled chamber to provide ballast. Another option for this type of containment system is the expanding boom that does not rely on pressurized inflation to ensure buoyancy. This type of boom is usually lighter in construction than conventional curtain booms. An advantage of the expanding boom, however, is its ease and speed of deployment and reduced staff needs.

Table 6.10-3 Listing of Common Booms Suitable for Offshore

		Used By			
Manufacturer	**Boom Model**	**CCG**	**ECRC**	**HMDC**	**OSRL**
AllMaritim A/S	Norwegian Oil Trawl PL 600	X			
AllMaritim A/S	NOFI 600 V-Sweep		X		
AllMaritim A/S	NOFI 1000 V-Sweep	X	X		
Oil Stop Inc.	Deep Sea		X		
Ro-Clean Desmi	Ro-Boom 1500 (called *Sea* by OSRL)		X		X
Ro-Clean Desmi	Ro-Boom 2000 (called *Ocean* by OSRL)	X	X		X
Ro-Clean Desmi	Ro-Boom 2200			X	
Vikoma Int. Ltd.	Seapack (same boom as Oceanpack)	X			
Vikoma Int. Ltd.	Oceanpack (same boom as Seapack)	X	X		
Vikoma Int. Ltd.	Ocean Boom				X
Vikoma Int. Ltd.	Weir Boom (active boom - incorporates skimmer)				X

CCG – Canadian Coast Guard
ECRC – Eastern Canada Response Corporation
HMDC – Hibernia Management and Development Company
OSRL – Oil Spill Response Ltd.

Skimmer Types

A skimmer is a device that can be used to physically collect oil off the surface of the water. Each skimmer type has features that make it suitable for particular applications. The most important feature of a skimmer is its ability to separate oil and water in the waste stream. A summary of common offshore skimmers is provided in Table 6.10-4.

Table 6.10-4 Listing of Common Skimmers Suitable for Offshore Use

				Used By			
Manufacturer	**Skimmer Model**	**Skimmer Type**	**Astm Oil Type**	**CCG**	**ECRC**	**HMDC**	**OSRL**
Frank Mohn A/S	Transrec 200	Hopper/Weir	II,III	X			
Frank Mohn A/S	ACW-400	Disc/Oleophilic	Unknown	X			
Frank Mohn A/S	Hi-Wax	Drum/Mechanical	II,III,IV, V+	Developed high viscosity/waxy oils			
Pharos Marine Ltd.	GT-185	Hopper/Weir	I,II,III	X	X		X
Pharos Marine Ltd.	GT-260	Hopper/Weir	I,II,III	X	X		
Ro-Clean Desmi	Desmi 250	Hopper/Weir	I,II,III,IV			X	X
Ro-Clean Desmi	Ro-Skim	Boom/Weir	I,II,III,IV				X
Vikoma Int. Ltd.	Sea Devil	Disc/Mechanical	II,III,IV,V				X
Vikoma Int. Ltd.	Sea Skimmer 50	Disc/Oleophilic	I,II,III				X
Vikoma Int. Ltd.	Weir Boom [2]	Boom/Weir	II,III				X
Bohus Invest Int. AB	Walosep W2	Hopper/Weir	I,II				X

Hopper/Weir Skimmers

All weir skimmers rely on gravity to drain oil off the sea surface. Weir skimmers use a hopper positioned just below the top of the oil surface that allows the oil flow into the hopper where it is collected in a central sump and pumped away. These skimmers can be designed to work with a range of product, from light to highly viscous oils. Weir skimmers work best in thick (>5 mm) accumulations of oil and are usually placed in the apex of boom collection systems.

Boom/Weir Skimmers

Different skimmer technologies may be used in boom skimmers, but they all incorporate the skimmer into the face of the containment boom. Like conventional floating skimmers, the skimmer head must be positioned at the apex of the boom to ensure the most efficient operation.

Oleophilic Disc Skimmers

Oleophilic skimmers rely on the adhesion of oil to circular discs as they are rotated through oil on the sea surface. Scrapers on each side of the discs removes the oil as the discs rotate and deposits it into a central sump where it is pumped away.

Disc Skimmers

Two distinct operating principles are employed for the disc skimmers. Some models rely only on the oleophilic properties of the discs, while the others also depend on the mechanical action of the discs.

Star Disc Skimmers (Mechanical/Oleophilic)

This skimmer uses rotating discs resembling circular saw blades that claw oil into the central sump, where it is removed by an Archimedean screw pump. While the discs function primarily in a mechanical fashion, they have oleophilic properties as well. This skimmer is designed to work best with very viscous oil and has limited application for low viscosity products.

Drum Skimmers

Drum skimmers work on the principle that the rotating drum creates a surface current that draws floating oil into the drum. For heavy products, the drum physically grabs the oil (similar to a belt skimmer). Inside the drum, the oil travels through a spiral casing to a central trough, where a conveyor screw pump carries away the oil. The perforated casing of the drum is designed to allow water to escape.

In 1998, Statoil sponsored the development of a skimmer to recover high-viscosity, waxy crude oil in cold water conditions of the North Sea (Statoil 1999). The Framo Hi-Wax skimmer has now been proven to be capable of handling very high viscosity oils. Only a limited number of these skimmers have been built to date. None are available in Canada.

Current Availability of Containment and Recovery Equipment

For Stage 1 actions, Husky Oil will have a dedicated first response capability at the White Rose production site. Under mutual aid, Husky Oil may also have use of the HMDC single-vessel side-sweep system and Terra Nova site resources. As part of the planning for the White Rose oilfield development, Husky Oil will continue to work with other operators to identify equipment needs and where appropriate, supplement existing resources. For Stage 2 and Stage 3 spill response operations, larger containment and recovery systems will be mobilized onshore. In every case, these systems are two vessel J-configurations. A summary of the equipment groupings available is shown in Table 6.10-5.

Table 6.10-5 Summary of Containment and Recovery Systems Available to White Rose

Boom Type	Size (mm)	Seastate (m)	Skimmer	Skimmer Type	De-rated Pumping rate (m^3/hr)	ASTM Oil Type
(HMDC) Ro-Boom Side Sweep	1700	2	Desmi 250	Weir	20	I,II,III,IV
(ECRC) NOFI 1000 Wide Swath	2350	3	Pharos GT 260	Weir	20	I, II, III
(ECRC) NOFI 600 Narrow Swath	1750	2.5	Pharos GT 260	Weir	20	I, II, III
(CCG) NOFI Oil Trawl Side Sweep and Guide Boom	1372 SS 1702 GB	1.5	Pharos GT 260	Weir	20	I, II, III
(CCG) NOFI VEE-Sweep and Guide Boom	2350	3	Pharos GT 260	Weir	20	I, II, III

6.10.4.7 Staff Requirements

Stage 1 personnel will be drawn from the crews of the FPSO, MODU and the support vessels. Select members of the Onshore ERT, the ECRC spill response manager, and the Canadian Coast Guard marine advisor may provide support on shore. If necessary, operational personnel will be flown to the FPSO to augment the crew at site. Depending upon the scale of Stage 2 or Stage 3 operations, personnel may be enlisted from a variety of sources to respond to a White Rose offshore oil spill:

- White Rose Offshore and On-shore ERTs;
- White Rose offshore personnel;
- Husky Oil CERT;
- Terra Nova OECT;
- HMDC OECT;
- ECRC Spill Management Team;
- ECRC First Response Team;

- Canadian Coast Guard Environmental Response Division personnel;
- Canadian Coast Guard marine crews;
- Provincial Airlines Limited surveillance crews; and
- OSRL operations personnel.

6.10.4.8 Waste Oil – Temporary Storage and Disposal Options

The progress of any oil spill clean up is ultimately limited by the ability to store and dispose of the collected oil. In the field, temporary storage of oil, oily water, and emulsified oil is an important issue. Storage on the collection platform, either in portable deck tanks or permanent built-in tanks, is an easy, temporary measure. As the volume of collected oil increases with time, barges or tankers will be required to hold the oil.

The *Atlantic Eagle* has a waste capacity of 1,200 m^3 and *Maersk Norseman* and *Maersk Nascopie* have 1,000 m^3 DNV class oil recovery tanks. All other offshore supply vessels have liquid mud tanks (approximately 300 m^3) that might be available for storage of waste oil at the time of a spill.

Ultimately, recovered oil may be disposed of in a number of ways: through re-introduction to the production stream on the platform; as fuel in the boilers of one of the three Newfoundland pulp mills; in the kiln at the North Star Cement plant in Corner Brook; or through a refining or recycling process. The White Rose Oil Spill Response Plan will detail which of these options are viable.

6.10.4.9 Shoreline Operations

In the unlikely event that oil spilled at the White Rose production site is transported to shore, Husky Oil will rely upon the capability of ECRC to respond to a coastal spill. ECRC has area-specific response plans for all parts of the Newfoundland coast, as well as considerable equipment and personnel resources selected specifically for local operating conditions. The ECRC area response plans are now supported by the EC coastal mapping system, which describes the detailed structure and sensitivity of the shoreline and provides continuous site-specific response assessment advice for the entire coastline of Atlantic Canada.

6.10.4.10 Effects Monitoring

Husky Oil will develop a process to implement a dedicated environmental effects monitoring program to determine the effects of major spills. The structure of the monitoring program will consider the structure of the environmental effects monitoring program established for routine production activities at White Rose. The decision to implement such a program will be made after consultation between Husky Oil and the C-NOPB and will be based on the circumstances of the spill.

7 MONITORING AND REPORTING

7.1 FOLLOW-UP – EFFECTS PREDICTIONS

Husky Oil proposes to implement monitoring programs focused on testing hypotheses built on the effects predictions in this document, and to verify the models used. As detailed in Chapters 4 and 5, the following programs will be developed.

7.1.1 Fish and Fish Habitat VEC

A comprehensive environmental effects monitoring program will be designed, focused on fish and fish habitat. The attributes proposed include:

- sediment quality as determined by the triad – sediment toxicity, sediment chemistry and benthic community analysis;
- water quality and primary productivity;
- fish body burden American plaice and commercially important snow crab;
- fish taint American plaice and commercially important snow crab; and
- fish health histopathology and MFO of American plaice.

A baseline characterization design report (Husky Oil 2000c) has been submitted to regulatory authorities for review. The results of the baseline characterization program will be documented, and submitted to the regulatory authorities. The baseline data will be reviewed, and an operational EEM program will be designed. It will link monitoring hypotheses to testable hypotheses, testing the validity of predictive models and effects predictions. It will be sufficiently robust statistically to allow natural variation to be distinguished from project-induced effects. It is Husky Oil's intention to link environmental management to the EEM program results (see also Chapter 8). The operational EEM design will involve stakeholder inputs, and will also be submitted for review by the regulatory agencies.

7.1.2 Sea Associated Birds VEC

Husky Oil conducted a supply vessel-based seabird monitoring program in conjunction with the 1999 drilling program and is continuing this program in 2000. Husky Oil will continue to review this program throughout the development phase of the project and, based on the program results, will make a decision as to whether to continue the monitoring program during the operation phase.

In addition, Husky Oil will record any incidental bird mortalities associated with physical and flare collisions. Husky Oil will also approach other Grand Banks' operators to evaluate participation in a Regional Program.

7.1.3 Oil Spill Monitoring

In the unlikely event of an accidental oil spill, Husky Oil will implement a dedicated oil spill monitoring program that focuses on marine birds in particular. Fish and fish habitat and marine mammals will also be monitored as part of that program.

The oil spill monitoring program will be designed to be statistically prudent, and will be submitted to the appropriate agencies in advance of execution for review.

7.2 FOLLOW-UP – HABITAT ALTERATION DISRUPTION OR DESTRUCTION

Husky Oil will comply with the requirements of any compensation agreement pursuant to DFO's Policy for the Management of Fish Habitat.

7.3 GRAND BANKS ENVIRONMENTAL EFFECTS MONITORING PROGRAMS

It has been recognized in the North Sea that a regional approach to environmental effects monitoring (EEM), with consistent methodology, provides information on the effects to extensive areas (cumulative effects) (Byrne 1999). A regional program has the potential to provide an understanding of the cumulative effects of offshore oil development on the marine-receiving environment (HMDC 1999).

Husky Oil is committed also to the regional approach to monitoring and will work with both other operators and any future ones to ensure the regional approach to resource monitoring and management is implemented.

The sequential development of the various oil fields on the Grand Banks will allow a temporal comparison of cumulative effects. The candidate monitoring parameters for Hibernia and Terra Nova's programs were carefully selected, building on the expertise from the North Sea and Gulf of Mexico and should contribute to the body of knowledge on marine receiving environments. Recognizing the benefits of a regional program, Hibernia Management and Development Company (HMDC), with cooperation from Petro-Canada, complemented their EEM design by adding a transect that originates on radial four of their sampling grid and connects with a transect of the Terra Nova sample grid. Husky Oil will integrate its monitoring with other operators.

All four East Coast Canada EEM programs (Cohasset-Panuke, Sable, Hibernia and Terra Nova) use methodology similar to, and adapted from, the methodologies from other jurisdictions, including the sampling grid and types of analyses conducted.

7.4 ENVIRONMENTAL EFFECTS MONITORING PROGRAM ATTRIBUTES

The monitoring variables chosen for the Hibernia EEM program were sediment quality, including sediment physiochemical characterization and sediment toxicity, and biota quality, including taint and bioaccumulation (HMDC 1996). Sediment quality included particle size analyses, total inorganic/ organic carbon, heavy metals, hydrocarbons and sediment toxicity. The sediment toxicity testing uses a battery of test organisms from various trophic levels and monitors both lethal and sublethal effects. The sediment toxicity assays incorporated into the Hibernia EEM program are amphipod (*Rhepoxynius abronius*) survival, juvenile polycheate (*Neanthes* spp.) growth and survival, and the luminescent bacterial (*Vibrio fischeri*) assay (Microtox™). Taint, trace metal and hydrocarbon analyses are assessed in American plaice captured near the Hibernia site and a reference site located approximately 50 km to the northwest of the Hibernia site. The presence or absence of taint is determined through the use of the triangle test and hedonic scaling techniques.

The monitoring variables chosen for the Terra Nova EEM program were sediment quality using the triad approach (which involves sediment chemistry, benthic invertebrates and sediment toxicity), physical and chemical water quality properties, and biota taint, bioaccumulation and health (Petro-Canada 1998). Sediment quality is comprised of the same components as the Hibernia program, plus benthic community profiles (conducted by traditional benthic community identification and assessment techniques that include various diversity indices, richness and evenness measurements). The sediment toxicity assays incorporated into the Terra Nova EEM program are the same as the Hibernia EEM program, excluding the juvenile polychaete growth and survival assay. Taint, trace metal and hydrocarbon analyses were conducted as per the Hibernia EEM program using American plaice and Icelandic scallops captured near the Terra Nova site and a reference site. American plaice were included for comparison with the Hibernia program, which has an insufficient Icelandic scallop population to support a monitoring program.

Differences between the Hibernia and Terra Nova EEM programs include the inclusion of water column profiling and fish health determination in the Terra Nova EEM program. The Terra Nova EEM baseline characterization program included a water column profile that captured data on pH, temperature, salinity, dissolved oxygen and chlorophyll with sampling for trace metals and hydrocarbons at selected stations (Petro-Canada 1998). Fish health is characterized by examining MFO induction, gill histopathology, liver histopathology, blood haemotology, life history measurements (age, growth and fecundity) in American plaice.

The White Rose baseline characterization design will collect information on the same parameters (attributes) as the Terra Nova program. Analyses will focus on sediment quality, water quality and biota (American plaice (for comparison with Hibernia and Terra Nova) and snow crab (an economically important species)).

7.4.1 Tainting

Potential tainting of commercial fish has been identified as an issue associated with hydrocarbon development on the Grand Banks.

Petroleum exploration/production activities and oil tanker traffic in coastal and shelf marine areas carry the risk of petroleum spills, discharge of produced water and drill cuttings. These activities pose risks of hydrocarbon contamination to a variety of marine habitats found within the water column and at the water-sediment interface. One of the potential effects on the marine biota occupying these habitats is 'tainting' (S.L. Ross Environmental Research Limited 1992).

The technical term 'tainting' was introduced to designate gustatory and/or olfactory impairment of foods. In 1982, GESAMP defined tainting in marine organisms as "a foreign flavour or odour in the organisms induced by conditions in the water to which the organisms are exposed". Off-taste is considered as a warning sign, indicating an onset of enzymatic degradation and bacteria-associated spoilage, especially with regard to fish (Höfer 1998a; 1998b). Although the contaminants causing taint may not be present in the tissues at concentrations high enough to cause acute damage to the organism, the perception of contamination can negatively impact a fishery (S.L. Ross Environmental Research Limited 1992). For example, fish farming was impaired for two years in the *Braer* accident area (Scotland) although relatively few fish near the accident site were even slightly chemically contaminated (Höfer 1998b).

Although chemical tainting has been observed, there have been only a few systematic studies of its occurrence and its causes. Tainting has occurred mostly in extremely polluted waters and subsequent to major coastal tanker accidents. There are no reports suggesting an impairment of the flavour of marine fish as a result of tank cleaning or oil discharge at high sea. Increased levels of hydrocarbons were found in fish from production platform sites in the North Sea, but these levels were not associated with any impairment of flavour (Parker et al. 1990).

Taint can only be determined by human senses. Without the establishment of relationship between taint determined by organoleptic sensory evaluation and chemical concentration, data on chemical presence alone cannot determine the presence of taint (Botta 1994). Tainting by oil is a complex problem to study for at least two reasons. First, taint is a subjective assessment rather than an objective analytical one. The detection threshold of tainting chemicals in fish tissues may vary somewhat from person to person. Second, the threshold tainting concentration varies from compound to compound, and since oil is a mixture of compounds, oil tainting is the result of a mixture of odiferous compounds acting together. Although no single compound may be concentrated enough to cause tainting on its own, the group of compounds acting together may collectively cause taint. Therefore, it is difficult to establish a direct relationship between the concentration of petroleum hydrocarbons in the fish flesh and the occurrence of tainting. Therefore, there is some belief that the only truly reliable measure of absence/presence of taint is by taste testing (S.L. Ross Environmental Research Limited 1992).

With respect to the assessment of mixed flavour changes, no testing methodologies have been sufficiently studied with regard to their reproducibility and reliability. Sensory assessment must account for the commonly occurring variations in the odour, taste and flavour of foods (Höfer 1998a). GESAMP (1982) did not include any testing procedures. Verified test recommendations were published by the European Chemical Industry Ecology and Toxicology Centre (ECETOC) in 1987 and by GESAMP in 1989. Presently, the testing methods proposed by ECETOC and GESAMP have been applied to fewer than 40 substances (Höfer 1998a).

Comparative studies with different fish and crustacean species are not available in the numbers required for an extrapolation of laboratory results to the natural environment. Although the risk of an impairment of flavour could be established, estimation of the risk involved after ship accidents must consider additional factors including total mass of pollutant spilled, dilution, water movement, resultant exposure period for the biota, physico-chemical properties of the substances involved and season. All of these factors help determine the environmental behaviour (such as, vaporization, sedimentation) of the spilled substance (Höfer 1998a).

Jardine and Hrudey (1999) reported results from a sensory evaluation using the Consistent Series Threshold Method. The results demonstrated substantial variability in the responses of panellists while the method uncertainty was tolerably narrow. The study indicated that the use of response variability and method uncertainty analysis in odour perception research is invaluable in result interpretation.

Sensory evaluations using taste panels were conducted on tissue samples of American plaice and Iceland scallops in an attempt to determine baseline taint in the vicinity of the Hibernia field (JWE 1995). Two types of evaluation were used during this procedure; 1) discriminative evaluation by 'triangle tests', and 2) preference evaluation by 'hedonic scaling'. It was recommended that both sensory evaluation techniques continue to used during the subsequent EEM program. Numerous sampling procedures and tainting assessment methods are discussed in Tidmarsh et al. (1985).

Höfer (1998a) concluded that tainting is low in importance compared to the chemical contamination of seafood. He questioned the testing of industrial chemicals for their tainting potential, calling that approach too expensive and its value for the protection of the marine environment questionable. Höfer contends that from a scientific standpoint, funds could be better used for the testing of chemicals concerning their potential to biodegrade and to bioaccumulate rather than their tainting potential.

Tainting is not expected to be a problem at White Rose, nor is it expected to be cumulative to other projects in this regard. It should be recognized that any oil releases, other than accidental, will be strictly regulated. It should also be noted that successful commercial fisheries have co-existed in the Gulf of Mexico and the North Sea for many years in the presence of thousands of oil wells without significant tainting problems.

Nonetheless, a program to monitor tainting in fish will be implemented for the White Rose oilfield. This monitoring program will consider all sources of hydrocarbons that could be released during development and production at the field. If tainted fish (snow crab) are found, the source will be determined and further mitigation measures will be implemented.

7.5 SAMPLING GRIDS

The Hibernia sampling grid was developed assuming total random likelihood of occurrence of relevant variables, with the discharges uniformly distributed around the production facility (Seaconsult 1994), with detectable accumulations/effects occurring within a 1-km radius (that is, the effects would follow a standard Gaussian distribution with routine decrease outward from the point source discharge) (HMDC 1996). A routine sampling pattern assumes a series of radii and concentric circles on a geometric progression outward from the Hibernia production facility. Eight radii based on compass directions were used, with the concentric rings selected to represent zones of influence as described in the Seaconsult (1994) model. A review of the 1998 data (Production Phase EEM – Year One (HMDC 1999)) indicated that effects were observed at stations 250 m along radial 2 and 8, which correspond to the location of the shale chutes on the production platform for the disposal of drill cuttings. The next stations along radial 2 and 8 were at 750 m and it was decided that additional stations were required within 1,000 m of the production platform to better characterize the spatial distribution of the discharges associated with the platform production (primarily the drill cuttings).

The development of the sampling grid design for Terra Nova was more complex than that for Hibernia as the design had to account for multiple source discharges (Petro-Canada 1997). This is similar to White Rose in that there will be multiple source discharges. Stations were located along three transects; each transect passed through one or more proposed drill centres. Stations were initially placed at 250, 500, 1,000, 2,000, 4,000 and 8,000 m from the proposed drill centres in two directions (inbound and outbound). The position of the stations inbound and outbound resulted in overlap as the stations from one drill centre ran into stations from another drill centre. This resulted in a few redundant stations that were eliminated. Two control stations were added at 20 km to the southeast and southwest. Control stations were unable to be added to the north due to proximity of other developments. The proposed drill centres had changed slightly after the baseline characterization had been completed. These changes had little or no effect on stations greater than 2,000 m distant from the drill centre. However, some of the near-field stations were affected and were no longer near drill centres. Several new stations were added close to the new drill centre positions and others stations, primarily the former 250- and 500-m stations were deleted as redundant.

A draft baseline characterization design grid for White Rose has been developed using the same concept as Terra Nova (that is, a radial sampling grid focussing on the multiple point sources of effects – the glory holes (drill cuttings) and FPSO (produced water)). Attenuation by distance will underline the statistical design.

7.6 WHITE ROSE BASELINE CHARACTERIZATION DESIGN

Husky Oil has designed a sampling program for determining the marine fish and fish habitat baseline conditions at White Rose against which future EEM program results will be compared. This baseline characterization design document has been submitted to the C-NOPB, DFO, EC and NDOEL for review. Husky Oil is committed to be part of a regional EEM program and to make data collected during White Rose EEM programs and the results of such programs available to other interested parties.

8 ENVIRONMENTAL MANAGEMENT

Comprehensive Environmental Management Systems (or Health, Safety and Environment (HS&E) Loss Control Management Performance Standards) have been adopted by most industries. Environmental Protection Plans (EPP) were the precursors of Environmental Management System (EMS) and today, an EPP is usually but one aspect of an overall system guided by a policy driven down from the top leadership in a company. Hence, in this chapter, Husky Oil discusses its corporate commitment to environmental management and environmental protection planning.

8.1 GENERAL HEALTH, SAFETY AND ENVIRONMENT POLICY STATEMENT

Husky Oil has developed and implemented a HS&E Policy that guides the company in all aspects of its business. This policy, plus the programs and procedures that support it, assist Husky Oil to be both responsible and duly diligent in its stewardship of health, safety, and the environment. The Husky Oil Policy is endorsed by the Chief Executive Officer (CEO) of the Corporation and by the Manager of East Coast Development and Operations; it is included as Figure 8.1-1.

A key document, which supports the HS&E Policy statement, is Husky Oil's East Coast Operations "Health, Safety and Environmental (HS&E) Loss Control Management Performance Standards" (Husky Oil 1998a). The stated purpose of that document is "to establish specific Health, Safety, and Environmental Loss Control standards for the Husky Oil East Coast Operations". Furthermore the document states that adherence to these standards will assist in meeting the following objectives:

- keep employees (Husky Oil and contractor) free from harm;
- ensure that project facilities and operations are run in a manner that demonstrates Husky Oil's commitment to HS&E stewardship to its employees, neighbors, regulators and the general public;
- manage risk to protect Husky Oil from loss;
- manage the effects of Husky Oil's operations on the environment and the liabilities associated with those impacts;
- ensure clarity of expectations and appropriate consistency in the company's HS&E loss control program; and
- facilitate consistent company wide application of The Husky Oil Loss Control Management (LCM) Program.

The following sections outline some of the key elements of the HS&E LCM system.

Figure 8.1-1 Health, Safety and Environment Policy

HEALTH, SAFETY AND ENVIRONMENT POLICY

We insist on a high level of concern for our employees, contractors, communities, customers and the environment. In conjunction with our business objectives we are striving to be one of the leading edge corporations in Health, Safety and Environmental stewardship and believe we can achieve this goal by managing our business under the following principles and values:

LEADERSHIP

High quality Health, Safety and Environmental stewardship is one of our corporate priorities and achieving this requires leadership, commitment and dedication of resources. We will include Health, Safety and Environmental objectives as part of our work and annual strategic plans.

RESPONSIBILITY

Health, Safety and Environmental protection is the responsibility of all employees and contractors. We will promote Health, Safety and Environmental awareness and respond promptly to and work diligently with all our stakeholders.

ACCOUNTABILITY

We are accountable for our performance and it will be measured against the Company's Health, Safety and Environmental Management Performance Standards. Safety and Environmental audits will be conducted on a regular basis to monitor compliance with the Standards, assess performance and identify areas where improvements are needed.

IMPROVEMENT

We will conduct our business activities with a progressive approach towards Health, Safety and Environmental protection and will monitor and if necessary, improve the performance of our operations. Improvements will be attained through planning, training and appropriate action.

Husky Oil

C.E.O.
HUSKY OIL LTD.

C.P. Bailey
MANAGER

8.2 FUNCTIONAL/DEPARTMENTAL RESPONSIBILITY FOR HEALTH, SAFETY AND ENVIRONMENT

Both Husky Oil and Contractor personnel involved in the Husky Oil East Coast Operations will participate in, and contribute to, the Project HS&E Loss Control Management system.

All shorebase and vessel management personnel will have specific HS&E LCM responsibilities clearly defined in their job outlines or descriptions, including any regulatory requirements involved in these responsibilities. In particular, the OIMs overriding authority to make decisions with respect to HS&E LCM issues shall be clearly identified. HS&E LCM responsibilities shall be included in employees' objectives and shall be evaluated as part of the annual performance appraisal. Copies of relevant documents concerning HS&E LCM responsibilities shall be provided to employees as appropriate.

8.2.1 Managers

Project managers will have primary responsibility for verifying/ensuring that the requirements of the HS&E LCM system are implemented and maintained. This would include development, implementation, review and revision of Project HS&E LCM performance objectives. On a periodic basis they will be responsible to:

- participate in the establishment of annual HS&E objectives for the Project and/or the Shorebase, FPSO, MODU, Support Vessels and their applicable departments;
- on a scheduled basis, attend and participate in regular HS&E meetings;
- perform HS&E LCM inspections of facility departments;
- ensure that an audit and report on compliance with all of the elements of the HS&E LCM Performance Standard is completed annually and recommend modifications when appropriate to enhance compliance;
- review quarterly HS&E performance indicators (for example, statistics) in relation to established objectives and discuss HS&E performance/issues as appropriate at management meetings;
- ensure that a member of the Project, FPSO, MODU or Support Vessel management team participates in the monthly facility HS&E Committee Meeting; and
- review with facility management any necessary changes or deviations to the established LCM system.

8.2.2 Supervisors

As part of their HS&E responsibilities, Supervisors will:

- participate in the establishment of annual HS&E LCM objectives;
- participate in the annual review of the HS&E LCM system as outlined above;
- carry out HS&E LCM inspections of their areas of responsibility ensuring that findings are documented and followed up;
- ensure their departments/areas hold HS&E meetings and that employees receive prompt feedback to the questions/suggestions; and
- require that all proposed equipment modifications are reviewed to ensure continued compliance with regulations and HS&E requirements.

8.2.3 Line Employees

All line employees will have clearly defined individual HS&E responsibilities to carry out under the Project HS&E LCM system.

8.2.4 Loss Control Program Support

Husky Oil and its major Contractors will formally allocate appropriate resources to ensure that all shorebased and offshore facilities will have sufficient designated resources to assist with HS&E LCM issues.

Written management performance standards for the HS&E LCM program will be prepared and updated on an as required basis.

Specific LCM procedures will be developed, as appropriate, to comply with Operator/Contractor corporate-wide standards and with regulations. HS&E Policies and Procedures Manuals (both corporate and facility-specific) outlining standards, policies and procedures and offering guidance will be maintained and updated on an annual basis.

All shorebased and offshore facilities will have HS&E committees which are representative of all personnel at the worksite and function according to legislated requirements and individual company policy.

8.2.5 Environmental Training and Awareness

Training will be a key component to ensure effective implementation of environmental protection procedures. The HS&E LCM Performance Standards ensure that employees have the skills and knowledge to perform their job functions effectively. A training needs assessment process will identify individual employee needs. Another key component will be a heightened awareness on the part of all employees to appreciate the environment within which they are working and the measures that have been implemented to protect it. This awareness will be generated through various employee awareness programs such as seminars, videos, briefings and posters.

8.3 EMPLOYEE RIGHTS

8.3.1 The Right to Know

All employees of Husky Oil and Contractor(s) have a right to know of any working conditions that may in any way pose a hazard to health, safety or the environment. This awareness is fostered by Husky Oil through a variety of measures such as:

- initial orientation, including hazard awareness and reporting;
- health hazard identification, and communication of that information. Supervisors will ensure that all employees are properly informed and knowledgeable about the potential occupational health and industrial hygiene hazards related to their work, including the handling of hazardous materials to which they could be exposed;
- supervisors will require group HS&E meetings to be held to discuss HS&E related topics;
- crew HS&E Meetings will be held monthly (or more frequently as dictated by crew change requirements) with individual shifts and department personnel including both Husky Oil and regular Contractor staff;
- joint Health Safety and Environmental Committees will be established on board vessels as required by regulation and meetings will be held at least monthly; and
- recommendations raised at the meetings will be recorded and addressed by designated personnel and action will be followed up and tracked on an ongoing basis.

8.3.2 The Right to Participate

The right of employees and contractors to participate in identification and management of HS&E issues is fostered by Husky Oil as follows:

- all shorebased and offshore facilities will have HS&E committees which are representative of all personnel at the worksite and function according to legislated requirements and individual company policy;

- management personnel will encourage employees to raise HS&E LCM concerns to their supervisors, team leaders or management personnel at any time or at scheduled HS&E meetings, where concerns raised will be dealt with and recorded; and
- recommendations raised at meetings will be recorded and addressed by designated personnel and action will be reported at the next meeting.

8.4 INDIVIDUAL RESPONSIBILITY FOR HEALTH, SAFETY AND ENVIRONMENT

Husky Oil and contractor employees are encouraged by various measures specified throughout the Husky Oil HS&E LCM Performance Standards to assume personal responsibility for the health and safety of both themselves and for their colleagues on the facility, as well as for the protection of the Environment. This standard also states explicitly that observing and recognizing compliance with rules, policy and procedures is a responsibility of each employee.

8.5 QUALITY ASSURANCE

Husky Oil has developed HS&E LCM Performance Standards for its East Coast Operations, which mirror company standards across the country while recognizing the unique nature of the marine environment. The LCM Performance Standards are based on the International Safety Rating System, the International Marine Safety Rating System and the (DNV) Safety and Environmental Protection Rules.

The relationship between Husky Oil and its major contractors needs to be seamless. A key element in achieving that seamless relationship is the demonstrated compatibility of the HS&E LCM system of Husky Oil with that of its contractor(s). Husky Oil requires that its major contractors document how their LCM systems compare to that of Husky Oil, and how identified gaps are to be rectified, in order to achieve complete consistency. Husky Oil then conducts regular structured audits of the contractors' systems.

Husky Oil intends to implement a specific quality assurance system, across the whole development. It will be applicable to all contractors and suppliers in the conduct of their activities associated with the project. As well, Husky Oil will ensure that the conduct of all project tasks, and the quality of installation, are in accordance with applicable Canadian and Newfoundland offshore regulations.

Before going into production operation, Husky Oil will obtain the requisite Certificates of Fitness, and Letters of Compliance. An independent certifying agency will be engaged to monitor the project throughout its development phase and to confirm that the complete installation has been designed, constructed and installed in compliance with regulations.

8.6 ORGANIZATIONAL RULES

8.6.1 General HS&E Policies

At all facilities the HS&E Coordinators will require that Husky Oil's general HS&E policy is:

- posted in suitable locations where they are visible to all;
- contained in rule booklets, policy and procedure manuals, etc.; and
- referred to in all major training programs.

8.6.2 Rules Development, Communication and Evaluation

Project HS&E rules, policies and standards will be developed and maintained on an ongoing basis in consultation with the shorebased and offshore facilities. Management will be responsible for ensuring that these policies and procedures are reviewed, and updated as required. Where appropriate, site or vessel-specific HS&E rules and procedures will be developed to supplement corporate-wide rules, policies and procedures.

A specific area dedicated to posting HS&E material will be maintained in locations readily accessible to all employees at shorebase, FPSO, MODU, or support vessels. Current information concerning HS&E LCM, including rules, policies, and programs, will be posted to facilitate communication to all employees.

Individual HS&E rules will be reviewed on an on-going basis and updated as conditions warrant. All employees will receive an initial orientation, upon arrival at all offshore facilities, which will include an explanation of the following HS&E information:

- key policies/principles;
- general HS&E rules;
- emergency response procedures and responsibilities (for example, evacuation plans and drills);
- instructions essential for safe FPSO/MODU/ship operations;
- work procedures (for example, use of work permits) and potential effects of departure from them;
- LCM objectives and the employees' role in achieving them;
- hazard awareness and reporting;
- shipboard drug and alcohol policy and the process for monitoring compliance to the policy;
- legal/legislative conditions and employees' roles in meeting them (including approval, or permit requirements); and
- environmental sensitivities and programs (for example, waste management, discharge requirements)

Where necessary, employees will be tested, either orally or in writing, for understanding and knowledge of key rules following the initial instruction. Employees will be given a thorough review of key rules for their area at least once a year during HS&E meetings and a record will be kept of these reviews in Committee meeting minutes.

Transferred employees will receive updated training in rules and procedures specific to their new assignment prior to commencing regular duties.

All employees with specific HS&E responsibilities outlined in HS&E policies and procedures will be fully aware, trained and monitored through the facility performance management process in the execution of those responsibilities.

Commendation and re-training or discipline for compliance or non-compliance of rules will be administered consistent with shorebase, FPSO, MODU, or support vessel policies. Records relating to compliance or non-compliance of rules will be used to evaluate the effectiveness of methods used to review rules with employees. Observing and recognizing compliance with rules, policies and procedures is a responsibility of each employee.

Existing general and specialized rules, policies and procedures will be reviewed and updated at least on an annual basis, or as needs dictate. Distribution lists for this LCM material will also be reviewed. The findings and recommendations, with respect to policies and procedures, will be incorporated into the annual review of the overall LCM system.

An evaluation of the compliance with major rule requirements, in particular, safe work permits, will be carried out following any major or high potential incidents and at least on an annual basis.

8.7 ENVIRONMENTAL CLAUSES FOR CONTRACTORS

Husky Oil's HS&E LCM Performance Standards state that both Husky Oil and Contractor Management personnel involved in Husky East Coast operations are responsible for programs and directives under these standards (Section 1- Leadership and Administration). As well, all contractor agreements will include an environmental clause indicating that contractors must comply with standards respecting the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations* and guidelines respecting physical environmental programs during drilling and production activities.

8.8 AUDITS

Environmental audits will be conducted on a regular basis, within a prescribed frequency. Audits will evaluate the implementation of project LCM systems as well as physical conditions.

8.8.1 Health Safety And Environmental Inspections

All shorebased and offshore facilities will carry out HS&E inspections on a regular basis to identify conditions and practices which have the potential to cause health, safety or environmental problems, and have documentation, regarding these inspections which specify the following:

- those personnel responsible for conducting the inspections;
- frequency of the inspections;
- checklists to be used;
- written reporting, distribution, record keeping and follow up procedures;
- responsibility/confirmation to ensure that remedial actions are carried out in a timely manner along with analyses of the reports; and
- quality control system to ensure that inspections documentation is appropriately filed, by the local area Supervisors and that all personnel are aware of these procedures and have appropriate access to the documents.

This documentation shall be updated on a yearly basis or when significant changes occur.

The inspection program design will include, but will not be limited to, a consideration of the following general areas as they apply to the FPSO, MODU, supply vessels and shorebase facilities (dock, warehouse, offices):

- bridge;
- vessel offices;
- radio room;
- deck areas;
- engine room;
- living areas;
- galley;
- messes;
- drilling facilities/process areas and equipment;
- emissions monitoring and control equipment;
- effluent streams monitoring, treatment/control equipment;
- waste handling and storage facilities;
- maintenance/work shops;
- stores areas;
- bulk product containment/storage areas;
- fuel storage areas;
- loading and unloading areas;

- ballast control areas;
- relevant off site areas;
- spill response and control equipment;
- fire and emergency equipment;
- all product and chemical transfer points;
- contractor work sites;
- leak detection systems; and
- corrosion detection systems.

Designated personnel will ensure that copies of inspection reports are forwarded to the appropriate supervisors for follow up actions. Area Supervisors will ensure that inspection and follow-up reports are maintained on file as necessary. Records of deficiency reports will also be maintained on shore. Designated personnel will ensure that management and other appropriate personnel are kept regularly informed of all planned inspections, along with the details of remedial actions and their timing.

8.8.2 Preventative Maintenance

An inventory of critical parts, products, equipment and systems will be identified, established and maintained at the FPSO, MODU, supply vessel and shorebase facility in order to fulfil parts and maintenance requirements and associated record keeping. Suppliers of critical materials will be identified based on their ability to meet required specifications. This function will be coordinated by the supervisor in charge of maintenance.

Critical equipment and systems will be inspected on a regular basis as per the vessel's regular inspection program.

Note: Critical parts are those whose failure are most likely to result in a major loss to people, property and the environment. Critical systems include ballasting systems, standby equipment (for example, emergency generators, emergency steering, main engine manoeuvring controls) and inactive equipment (for example, lifeboat launching systems, mooring and anchoring equipment) and emission control systems.

Critical systems, monitoring instruments, and other equipment will be inspected, calibrated, and repaired as per manufacture's specifications and applicable company standards by maintenance personnel or other designated contractors.

8.8.3 Environmental Performance Targets

On an annual basis, or when significant changes occur, operations line management in consultation with the HS&E Coordinators and Corporate HS&E shall review and develop environmental performance objectives for their operations as part of the overall HS&E loss control objectives. These objectives will consider, and incorporate where appropriate, the following:

- energy use;
- emissions;
- pollution prevention, spills, discharges/releases;
- waste management; and
- compliance with relevant legislative requirements, approval requirements, codes of practice, etc.

Objectives will be:

- quantifiable, as much as possible;
- documented and published in a format which facilitates comparison to monitoring results, regulatory standards, etc.; and
- communicated to all relevant personnel on a timely basis.

A system will be in place for performance assessment including responsibility for:

- verifying if objectives have been met or reasons for non achievement of targets;
- identifying necessary remedial actions and verifying that remedial actions are implemented; and
- communicating the results of the performance assessment to relevant personnel on a timely basis.

A system for ongoing environmental performance monitoring will be in place which outlines:

- appropriate sampling, monitoring and metering methods and equipment requirements including performance specifications, maintenance and testing requirements;
- required sampling and analysis schedules; and
- report formats and distribution as well as record keeping and storage.

8.8.3.1 Atmospheric Emissions

An inventory of air emissions for the overall project shall be maintained by the Husky Oil corporate HS&E group. This inventory shall be updated yearly and shall include the following:

- flare gas emissions (CO_2/NO_x/VOC/CH_4);

- electrical energy use; and
- fuel consumption.

All facilities whose air emissions are governed by regulatory standards (including flaring restrictions, approvals/permits/licenses), will have documentation in place that is updated annually or when significant changes occur. It will include the following (as applicable):

- a listing of air emissions, including the amount of each of the emissions;
- operating specifications for air emissions control equipment;
- defined responsibilities for the operation, testing and maintenance of the air emissions control equipment, as per manufacturer's guidelines or design criteria; and
- procedures to ensure that relevant personnel are notified when air emissions exceed defined levels, and that appropriate actions are taken.

Greenhouse Gases

Husky Oil recognizes the importance of greenhouse gas emissions reduction and is a supporter of the Voluntary Challenge initiative as an integral part of Canada's National Action Plan. Husky Oil believes that options to deal with "Climate Change" should be investigated and pursued, where appropriate and, to this end, has set a target to reduce approximately 670,000 t of CO_2E by 2001 for its existing on-shore operations; cumulative reductions by the fourth quarter of 1999 were approximately 373,000 t CO_2E - more than 50 percent of the target. Husky Oil prepares and submits annually a Voluntary Action Progress Report to the Voluntary Challenge and Registry (VCR). The White Rose project will be added to the report, when it is in operation.

White Rose Greenhouse Gas Emissions

It is Husky Oil's goal to reduce emissions from its operations to as low as is reasonably practical through assessment and selection of appropriate equipment and technology and by focusing on energy conservation. This goal has already been identified and transmitted to potential contractors in the "Request for Proposal-Provision and Operation of White Rose FPSO". The primary approach to curtail emissions will be to ensure that emission reduction strategies are an integral part of the design of the production facilities and that appropriate procedures are in place, as part of the HS&E Loss Control Management Performance Standards, during operations. Measures already identified include:

- pre-drilling gas injection wells;
- designing efficient flaring systems; and
- recovering waste heat from gas turbines.

During operations, the strategy to reduce emissions will focus on:

- reinjection of associated gas;
- reduction of flaring;
- minimizing fugitive emissions; and
- optimizing supply and transport systems, including cooperation with other operators.

A greenhouse gas emissions estimate for White Rose is included in Section 4.3.2.13.

8.8.3.2 Discharges

All facilities, including shorebase operations whose liquid effluent discharges (including waste discharges) are governed by regulatory standards (for example, the current OWTG (NEB, C-NOPB and C-NSOPB 1996)), will have documentation in place that is updated on an annual basis or when significant changes occur. Documentation will include the following:

- a listing of liquid effluent discharges, including volumes;
- operating specifications for any liquid effluent discharge control equipment;
- defined responsibilities for the operation, testing and maintenance of the emission control equipment, as per manufacturer's guidelines or design criteria;
- procedures/equipment in place to prevent unauthorized discharges including containment systems such as barriers and dikes, double walled tanks, leak detection equipment and liners (shorebase sumps); and
- procedures to ensure that relevant personnel are notified when liquid effluent discharges exceed defined levels, and that appropriate actions are taken.

Where unauthorized discharges have occurred, actions will be taken to manage these situations as follows:

- the source of the contamination will be stopped, as soon and as much as possible;
- where feasible and applicable, the discharged materials will be contained and recovered;
- the risk to human health and the environment will be assessed; and
- depending on the results of the risk assessment above, and relevant regulatory requirements, a strategy will be formulated to address the contamination and, if applicable, the facility emergency response plan will be activated.

8.8.3.3 Solid Wastes

All shorebased and offshore facilities have a Waste Management Plan which is reviewed on an annual basis or when significant changes occur, and includes the following:

- waste types (including drill cuttings), sources and quantities generated;
- waste minimization options being used (including reduction, re-use and recycle options and waste segregation);
- acceptable disposal options;
- any special handling or documentation requirements, (particularly for wastes classified as dangerous or hazardous) including approved contractors/carriers, and contingency measures for waste management accidents;
- notification procedures to handle deviations from the plan, emergency situations, etc.; and
- roles and responsibilities with respect to classification, handling and documentation of the waste, and ensuring that proper procedures are followed throughout (including audit procedures).

Records regarding waste disposal will be kept in a manner which meets or exceeds the requirements of the relevant authorities. For offshore operations, requirements outlined by the current OWTG (NEB, C-NOPB and C-NSOPB 1996) will constitute the minimum standard.

8.8.3.4 Soil And Groundwater (Shorebase Operations)

Systems will be in place to monitor areas of facility operations that have the likely potential to contaminate soil or groundwater, or that have already caused such contamination.

For areas which have the potential to cause soil or groundwater contamination, the Contractors shall ensure that systems shall be put in place to manage these risks. These systems shall include, as appropriate:

- soil and groundwater monitoring systems;
- sampling, analysis and reporting procedures; and
- equipment monitoring and maintenance procedures.

8.8.3.5 Hazardous/Dangerous Materials Handling

A system will be in place to ensure:

- hazardous/dangerous materials are stored in compliance with applicable codes, standards and regulations;
- personnel handling these materials are properly trained;
- MSDS data sheets for all these materials are readily accessible to all employees handling them, and to the HS&E coordinators;
- there is an inventory, which is updated on a regular basis, of all such materials which are shipped to and from the shorebased and offshore facilities; and

- all shipments of hazardous/dangerous goods are properly packaged, labelled and placarded and accompanied by the proper documentation.

8.8.3.6 Electromagnetic Emissions Safety

On a MODU there are many sources of radio frequency emissions: these include microwave ovens to radar, handheld radios, MF/HF radios and both portable and fixed satellite terminals. For standard telecommunications devices like MF/HF and VHF transmitting antennas and satellite antennas. Husky Oil commits to:

- place transmit antennas in a normally unoccupied area;
- post signs showing safe working distance from antennas;
- placard and shut down/lock-out transmitters when maintenance workers are servicing the antenna;
- publish safety standards regarding working in areas containing sources of RF emissions; and
- educate workers and require all workers to comply with safety standards.

Husky Oil will comply with the specifications detailed by Health Canada for the use of radiation emitting devices (Health Canada 1999).

8.8.3.7 Community Relations

Husky Oil and its major contractors will participate, where appropriate, with local area users and community stakeholders for the purpose of:

- monitoring HS&E concerns and activities;
- offering to disseminate HS&E performance information; and
- developing an effective working relationship with local stakeholders.

A system will be in place for receipt and follow-up of external complaints or information requests (for example, from fisheries community) including responsibilities for dissemination of the information to relevant personnel and feedback/response to the complaint.

8.9 MITIGATION MEASURES FOR ROUTINE ACTIVITIES

The context for mitigation measures will be provided for routine activities as identified in Chapters 4, 5 and 6. Mitigation measures for routine activities will address:

- drilling muds;
- well-treatment fluids;
- produced water;

- storage displacement waters;
- deck drainage;
- solid and sanitary wastes;
- ship and boat noise;
- routing of ships to minimize disturbance to wildlife;
- routing, and minimum altitudes, for helicopters to minimize disturbance to wildlife;
- an anti-harassment policy for wildlife;
- onshore facilities;
- regulated inputs of crude oil;
- spill and response;
- atmospheric emissions; and
- fuel and chemical handling.

8.10 ENVIRONMENTAL PROTECTION PROCEDURES

Husky Oil will implement environmental protection procedures for all phases of the White Rose Development. This approach will recognize and provide for the varying activities associated with the different phases of development and will be an evolving, life-of-project planning exercise. This approach is consistent with the requirements of the C-NOPB's regulations and guidelines. Currently, it is anticipated that environmental protection planning will address the following activities or phases: drilling, production, and decommissioning and abandonment. The overall White Rose HS&E program will guide the preparation of phase/activity specific operational plans, each incorporating specific environmental protection procedures. A bridging document will be submitted to the C-NOPB for approval of development. An example of the elements that could be included in the bridging document is presented in Appendix 8.A.

To ensure the successful implementation of environmental protection procedures, it is imperative to have a clear description of the roles and responsibilities of all employees. This definition must include aspects related to accountability, lines of communication and reporting relationships. Husky Oil's HS&E LCM Performance Standards (Section1 – Leadership and Administration) clearly commits to assigning accountabilities and requiring management to define their expectations so that personnel know and accept their responsibility.

8.10.1 Precautionary Principle

The precautionary principle is understood to mean that: "*Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*." Husky Oil is committed to applying appropriate and cost-effective measures that will prevent serious or irreversible damage. The precautionary principle will be considered in planning, design and implementation. Husky Oil will require contractors to consider the best practical technology for all activities and use appropriate measures to prevent adverse effects.

8.11 ENVIRONMENTAL EFFECTS MONITORING (EEM) PROGRAMS AND REPORTING

An EEM program is an integral part of follow-up program required by CEAA. An EEM program will be established to assess the effects of operations on the marine environment (see Chapter 7). According to the C-NOPB, EEM programs are designed to detect and document any adverse environmental effects that may result from the operation of production installations. The results of these programs are to be used by regulatory authorities, in consultation with industry and other interested parties, to determine the continued adequacy of waste treatment technologies and disposal procedures which are used by operators to achieve the waste concentrations in the discharges cited in the current OWTG (NEB, C-NOPB and C-NSOPB 1996). EEM will also be conducted to verify effects predictions made during the environmental assessment, assess the effectiveness of the implemented mitigation measures, provide an early warning of changes in the environment, prompt corrective action and, ultimately, to improve the understanding of environmental cause and effect relationships.

The program will be designed to be specific to the White Rose operation and to allow integration into a regional EEM program. The program will incorporate a scientifically defensible design that considers all significant discharges and inputs to the marine environment, the natural variability of the marine environment and its components and all pathways into biological systems. It will emphasize hypothesis testing, and respond to scientifically-based predictions in the EIS. As documented in the EIS, it is anticipated that the focus of the EEM program for the White Rose project will be related to the zone of influence of drilling muds and cuttings (as measured in sediments) and discharges of produced water. Prior to its implementation, the EEM program will include review by relevant government departments (for example, EC, DFO and Newfoundland Department of Environment and Labour) through the approval process of C-NOPB. EEM commitments and regional EEM context are discussed in Chapter 7.

8.12 ENVIRONMENTAL COMPLIANCE MONITORING PRACTICES AND REPORTING

Compliance monitoring is conducted to verify adherence with applicable legislation and conditions of regulatory approvals. Compliance monitoring will primarily involve monitoring for conformance with the discharge limits identified in the current OWTG (NEB, C-NOPB and C-NSOPB 1996). Monitoring programs will be developed which provide the measurement and reporting of waste discharges that undergo treatment pursuant to the guidelines.

Husky Oil’s HS&E LCM Performance Standards (Section 11- Environmental Program) stipulate that a system for ongoing environmental performance monitoring will be in place. The system will outline appropriate sampling, monitoring and metering methods and equipment requirements, including performance specifications, maintenance and testing requirements and required sampling and analysis schedules.

8.13 PERMITS AND APPROVALS

A variety of permits and approvals are required, depending on the activities and phase of development. These permits and approvals will be specified during the approval process. In the EPP, applicable permits and approvals will be identified, along with reference to the appropriate legislation, act or regulation relevant to the activities being addressed during environmental protection planning.

8.14 OPTIMIZATION MEASURES FOR THE FISHING INDUSTRY

Chapter 7 of the SEIS (Part Two) discusses possible effects from activities associated with the White Rose Development and assesses the effects on the commercial fisheries. Potential effects discussed include damage to fishing gear or vessels, loss of access to fishing grounds, oil spills, labour information, communications and emergency response and cumulative effects. Optimization measures to be considered for incorporation into an EPP will include the establishment of safety zones, the establishment of effective and cooperative communication mechanisms between Husky Oil and other operators and the fishing industry, the careful selection of facility locations to minimize loss of access, the development of a compensation program in accordance with all applicable regulatory requirements and the establishment of shipping lanes.

The HS&E LCM Performance Standards (Section 8.8.3.7) provide for the establishment of a formal process for effectively managing community relations with the community. HS&E Coordinators are also responsible for ensuring a system is in place for receipt and follow-up of external complaints and information from the fisheries community.

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Appendix 2.A

Husky/Bow Valley East Coast Project
and
Husky Oil Operations Limited Well Sites
1984 - 1999

Listed below is the location and dates of the wellsites from which data is included in the Husky data set.

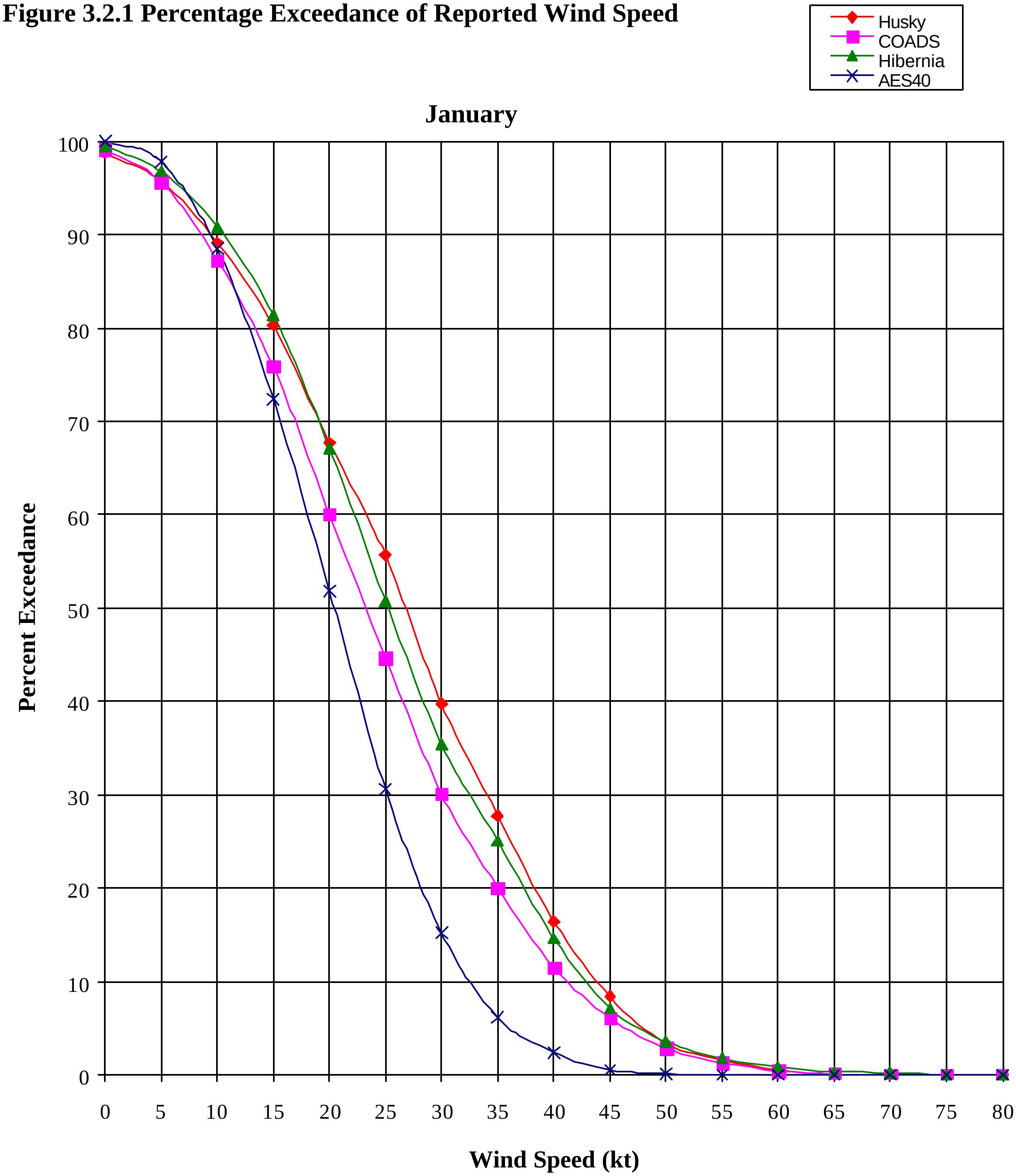
Wellsite Name	**Rig Name**	**Wellsite Coordinates**	**Start Date**	**End Date**
Voyager J-18	Sedco 706	46 27 32.50 N 48 17 00.49 W	25 Feb 84	12 Jun 84
Archer K-19	Bow Drill 3	46 38 43.17 N 48 02 18.42 W	25 Jun 84	16 Dec 84
Whiterose N-22	Sedco 706	46 51 47.99 N 48 03 56.51 W	26 Jun 84	05 Jan 85
Conquest K-09	Bow Drill 2	47 08 34.68 N 48 15 45.08 W	12 Nov 84 21 Apr 85 30 May 85	02 Feb 85 28 May 85 26 Jul 85
North Ben Nevis P-93	Bow Drill 3	46 42 48.10 N 48 28 34.24 W	16 Dec 84 27 Mar 85 21 Apr 85	03 Feb 85 31 Mar 85 31 Oct 85
Panther P-52	Sedco 706	47 01 53.37 N 47 37 43.83 W	05 Jan 85	25 Jan 85
Whiterose J-49	Bow Drill 2	46 48 31.30 N 48 06 27.51 W	27 Jul 85	12 Dec 85
Panther P-52 (re-entry)	Bow Drill 3	47 01 53.37 N 47 37 43.80 W	03 Nov 85	31 Jan 86
Whiterose L-61	Bow Drill 2	46 50 34.12 N 48 10 28.34 W	12 Dec 85 04 Mar 86 21 Mar 86	17 Feb 86 15 Mar 86 31 Mar 86
North Ben Nevis M-61	Sedco 710	46 40 53.57 N 48 25 18.60 W	09 Jan 86	31 Mar 86
Fortune G-57	Bow Drill 3	46 36 18.90 N 48 08 02.21 W	04 Feb 86 01 Mar 86	14 Feb 86 09 Sep 86
Whiterose L-61 (re-entry)	Bow Drill 2	46 50 34.12 N 48 10 28.34 W	10 Sep 86	04 Oct 86
Golconda C-64	Bow Drill 3	46 53 11.63 N 47 39 56.54 W	05 Oct 86	02 Feb 87

Wellsite Name	Rig Name	Wellsite Coordinates	Start Date	End Date
Bonne Bay C-73	Bow Drill 3	46 32 10.74 N 48 11 30.51 W	03 Feb 87 16 Mar 87 18 Jun 87	27 Feb 87 23 Apr 87 18 Jul 87
North Ben Nevis M-61 (re-entry)	Bow Drill 3	46 40 53.57 N 48 25 18.60 W	18 Jul 87	18 Aug 87
Whiterose E-09	Bow Drill 3	46 48 26 N 48 01 23 W	18 Aug 87 20 Apr 88	23 Feb 88 30 Jun 88
Whiterose A-90	Bow Drill 3	46 49 11.19 N 47 57 18.09 W	01 Jul 88	11 Aug 88
Whiterose L-08	B. Shoemaker	46 47 30.6 N 48 01 20.1 W	29 Mar 99	14 Jun 99
Whiterose A-17	B. Shoemaker	46 46 07.46 N 48 01 40.92 W	15 Jun 99	07 Aug 99
Whiterose N-30	B. Shoemaker	46 49 83 N 48 03 76 W	08 Aug 99	14 Oct 99

Appendix 2.B

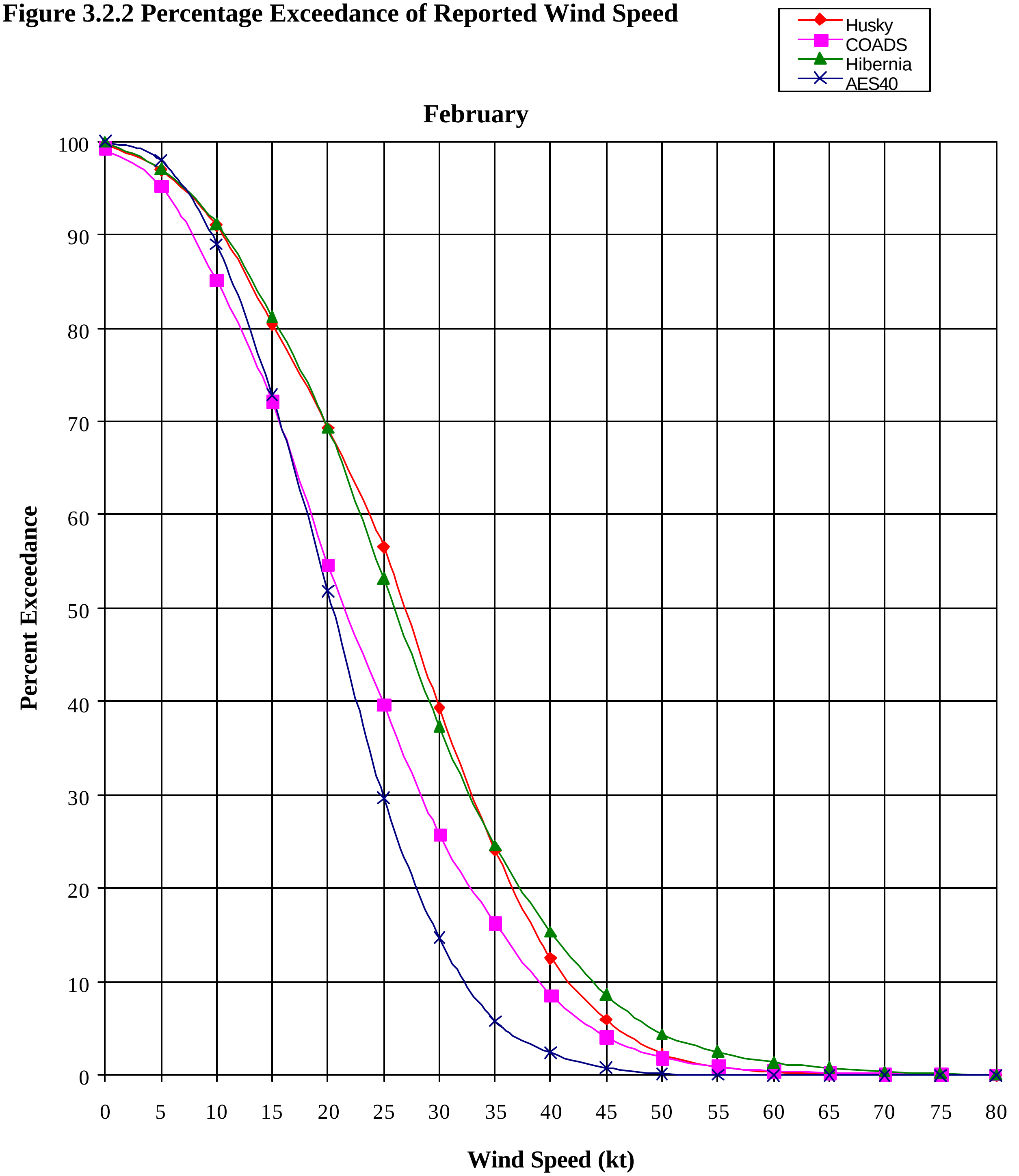
Wind Exceedance

Figure 3.2.1 Percentage Exceedance of Reported Wind Speed



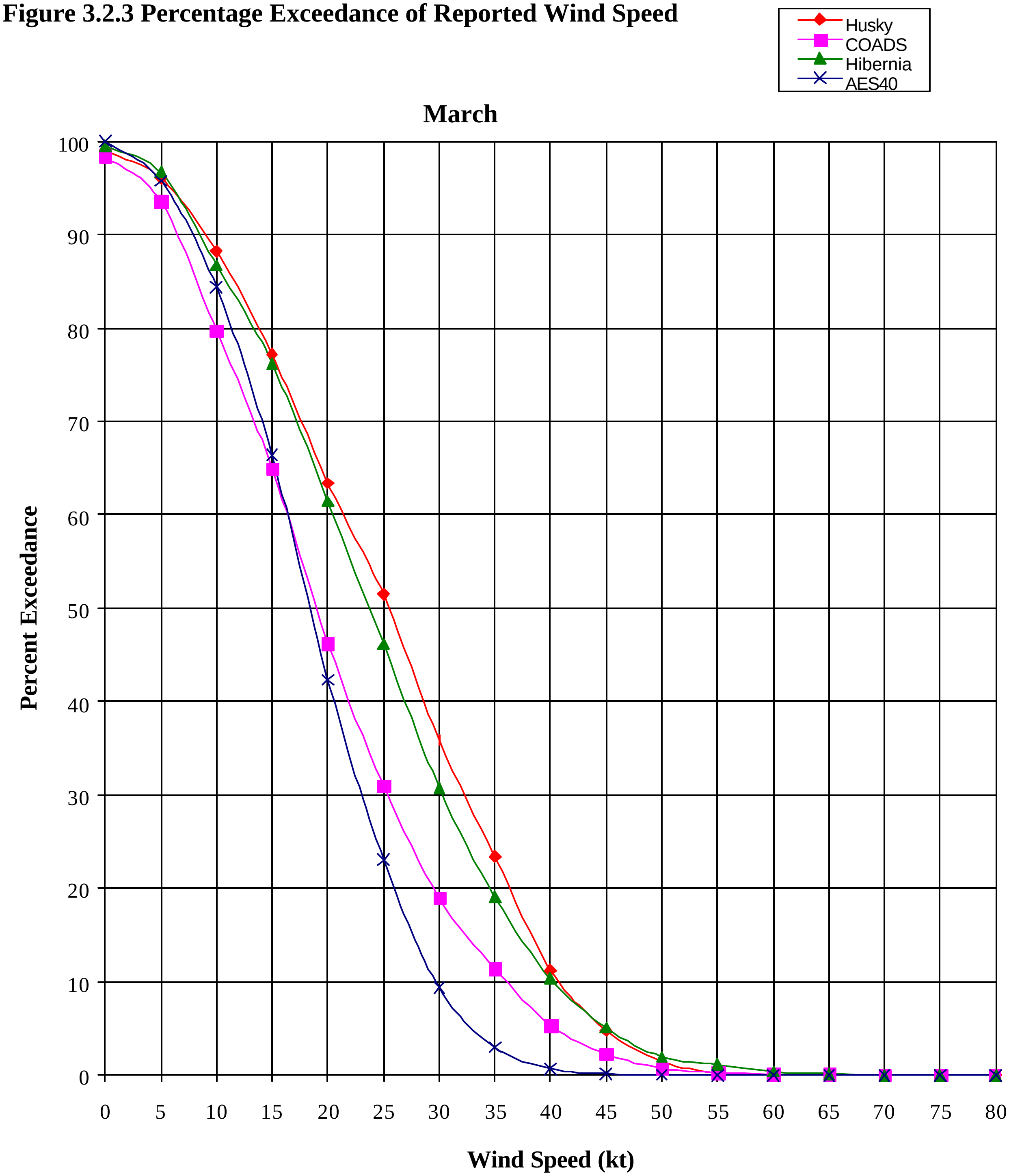
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.2 Percentage Exceedance of Reported Wind Speed



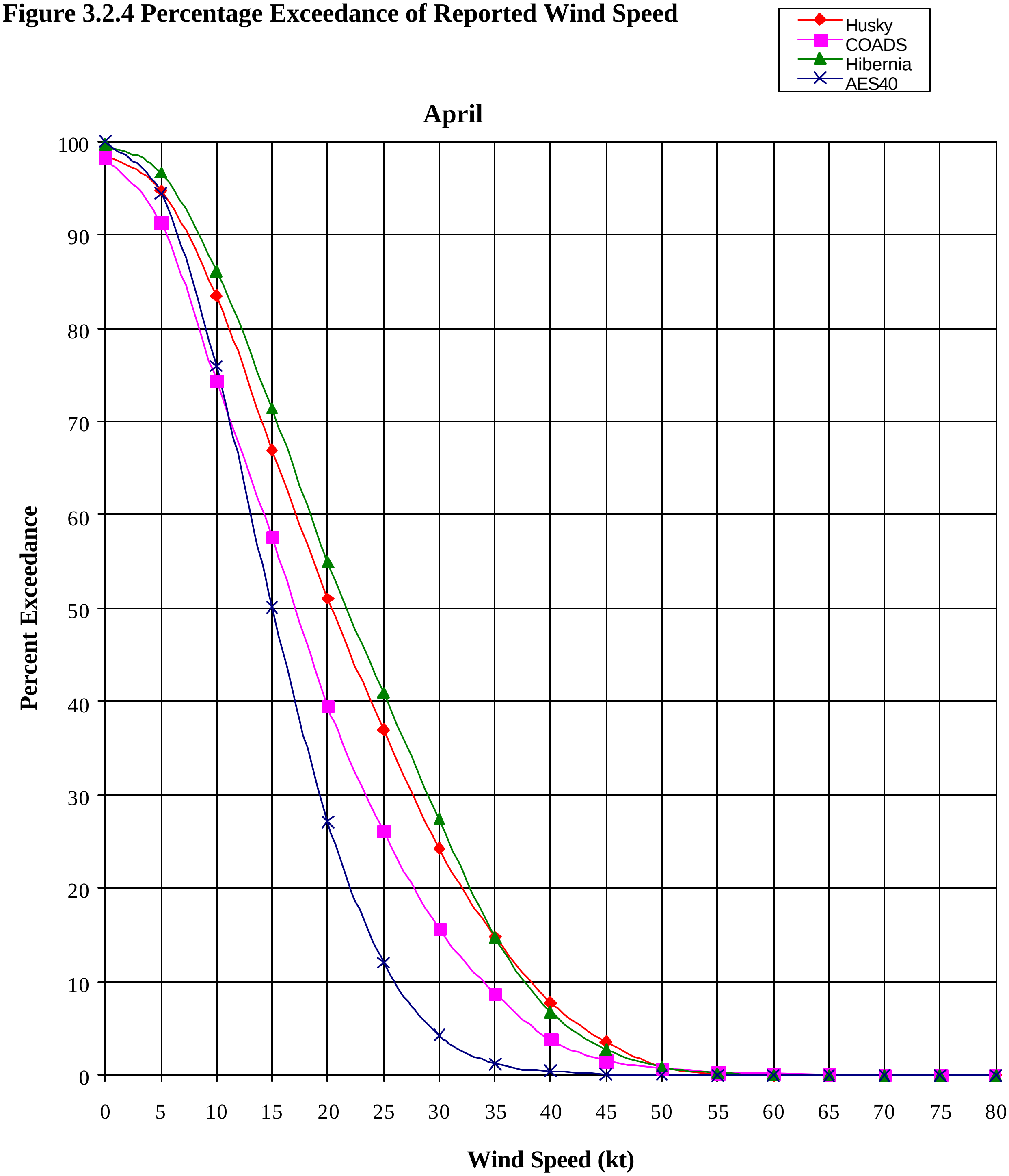
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.3 Percentage Exceedance of Reported Wind Speed



Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.4 Percentage Exceedance of Reported Wind Speed



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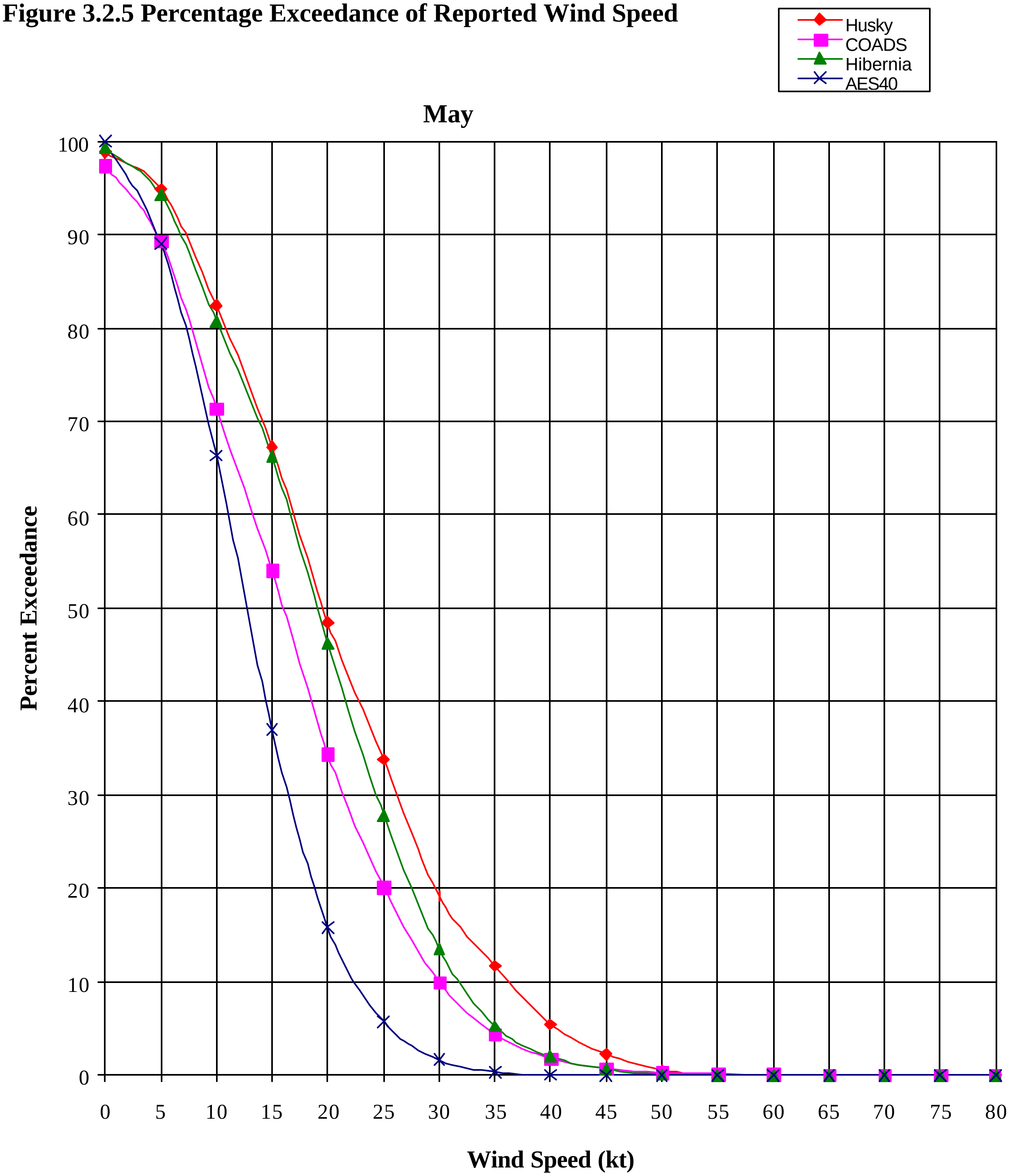
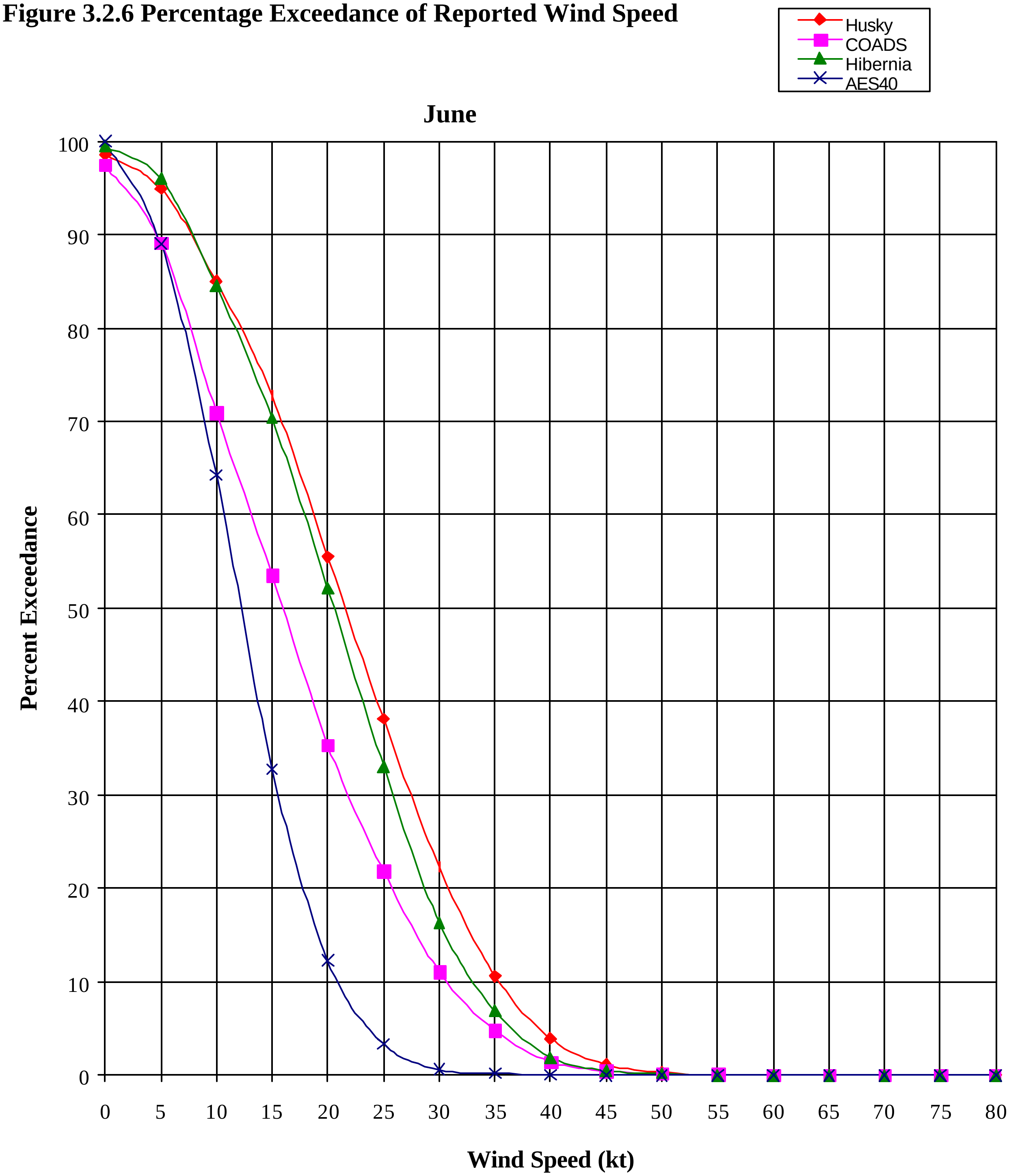
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.5 Percentage Exceedance of Reported Wind Speed



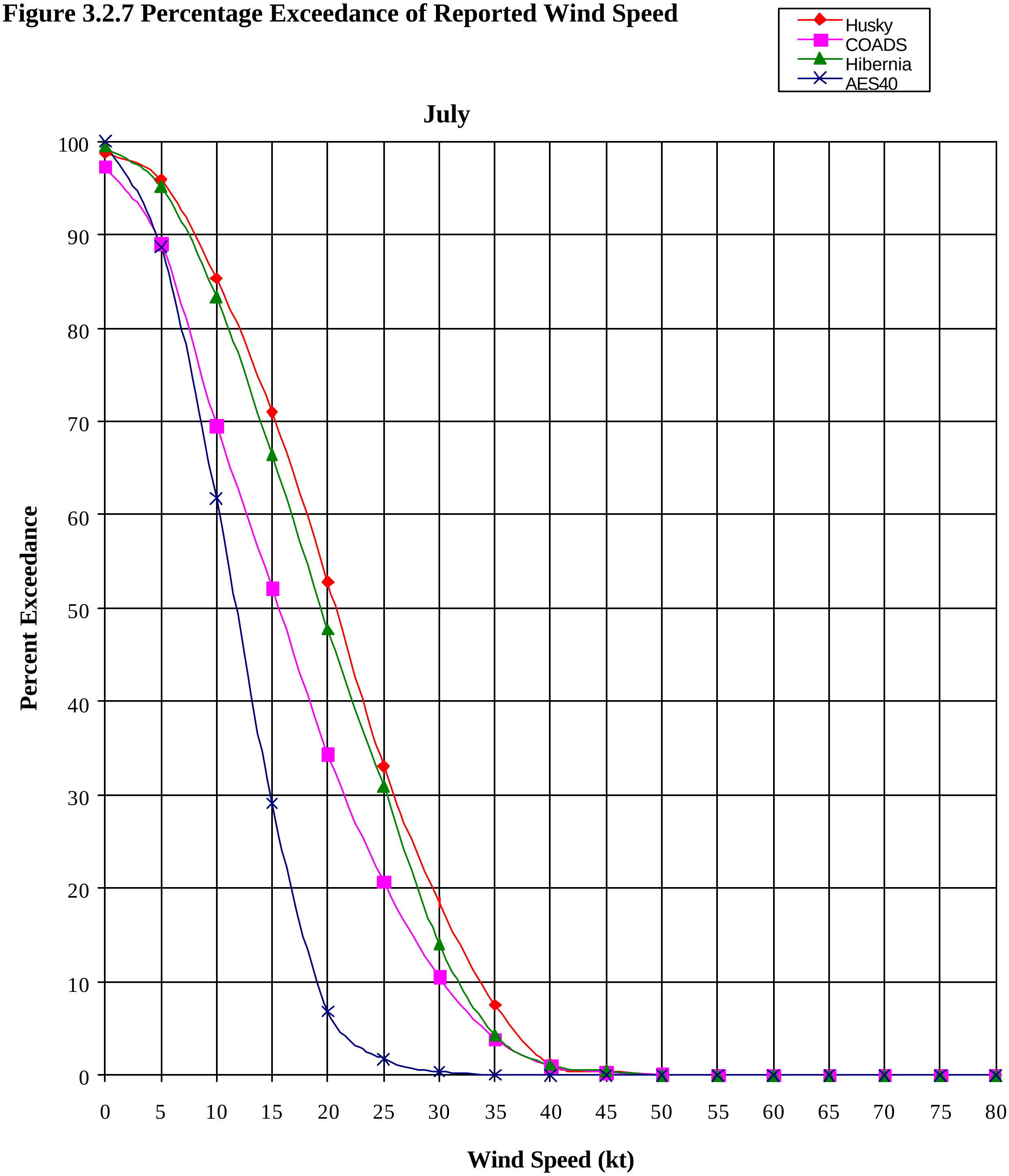
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.6 Percentage Exceedance of Reported Wind Speed



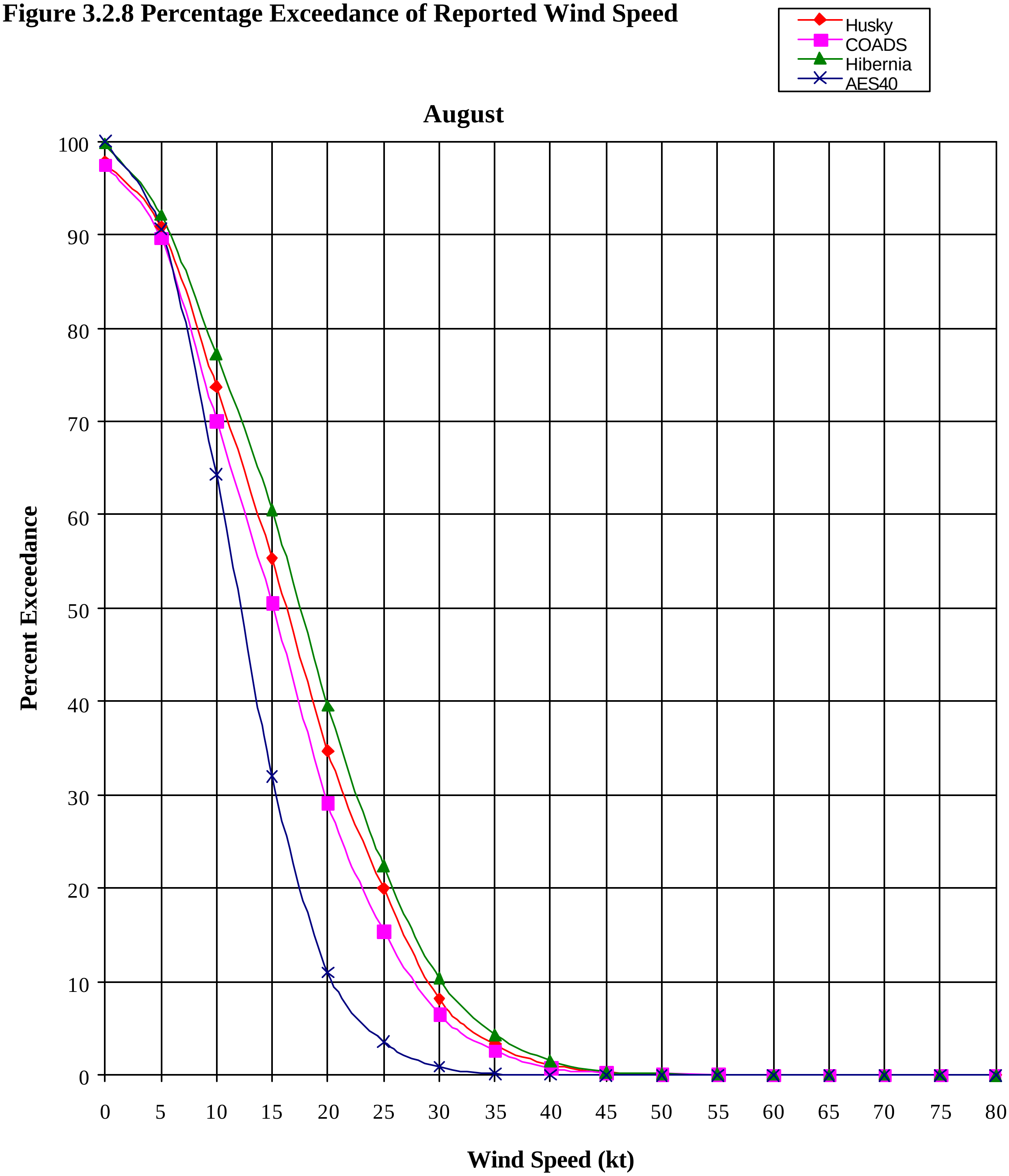
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.7 Percentage Exceedance of Reported Wind Speed



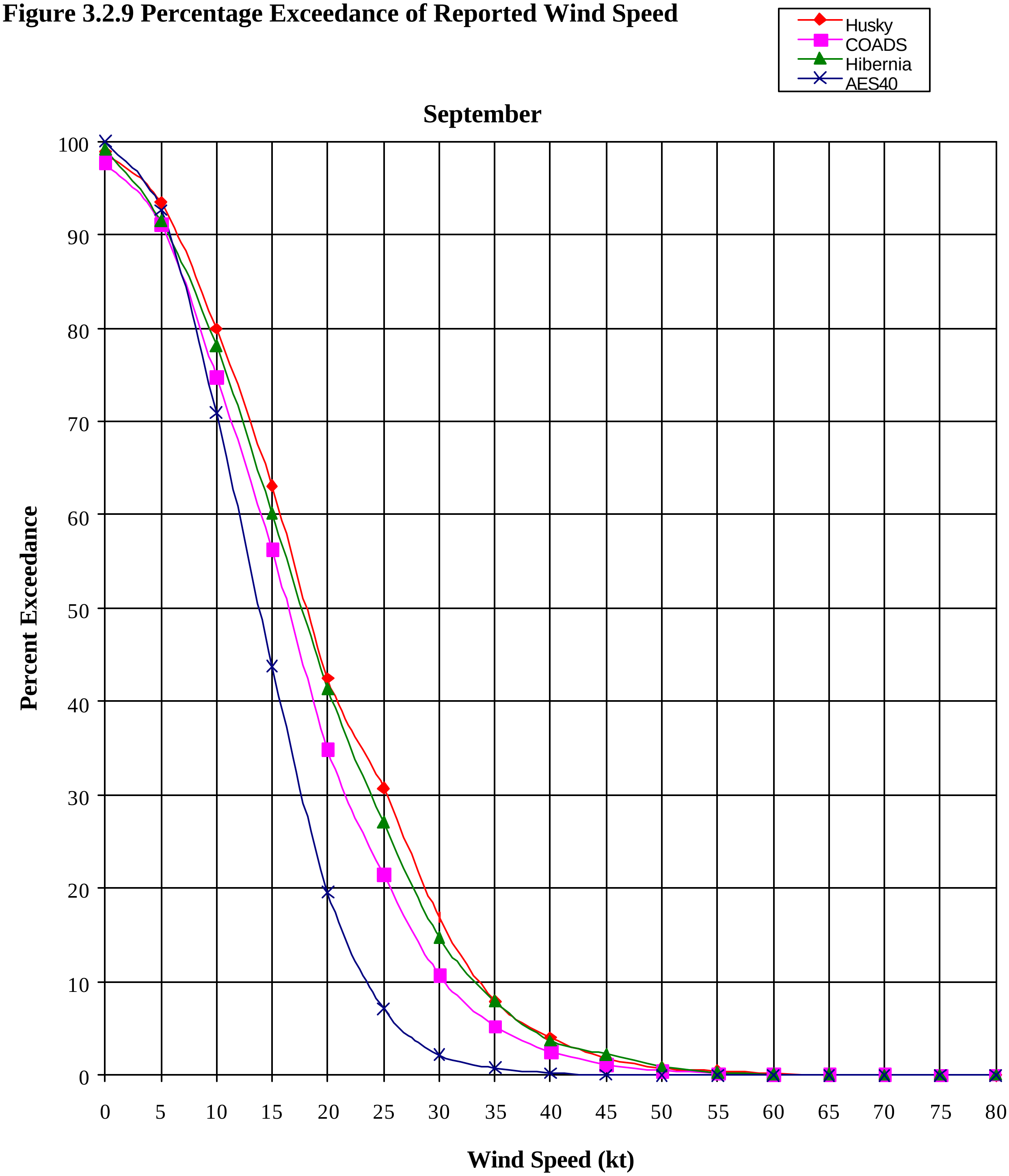
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.8 Percentage Exceedance of Reported Wind Speed



Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.9 Percentage Exceedance of Reported Wind Speed



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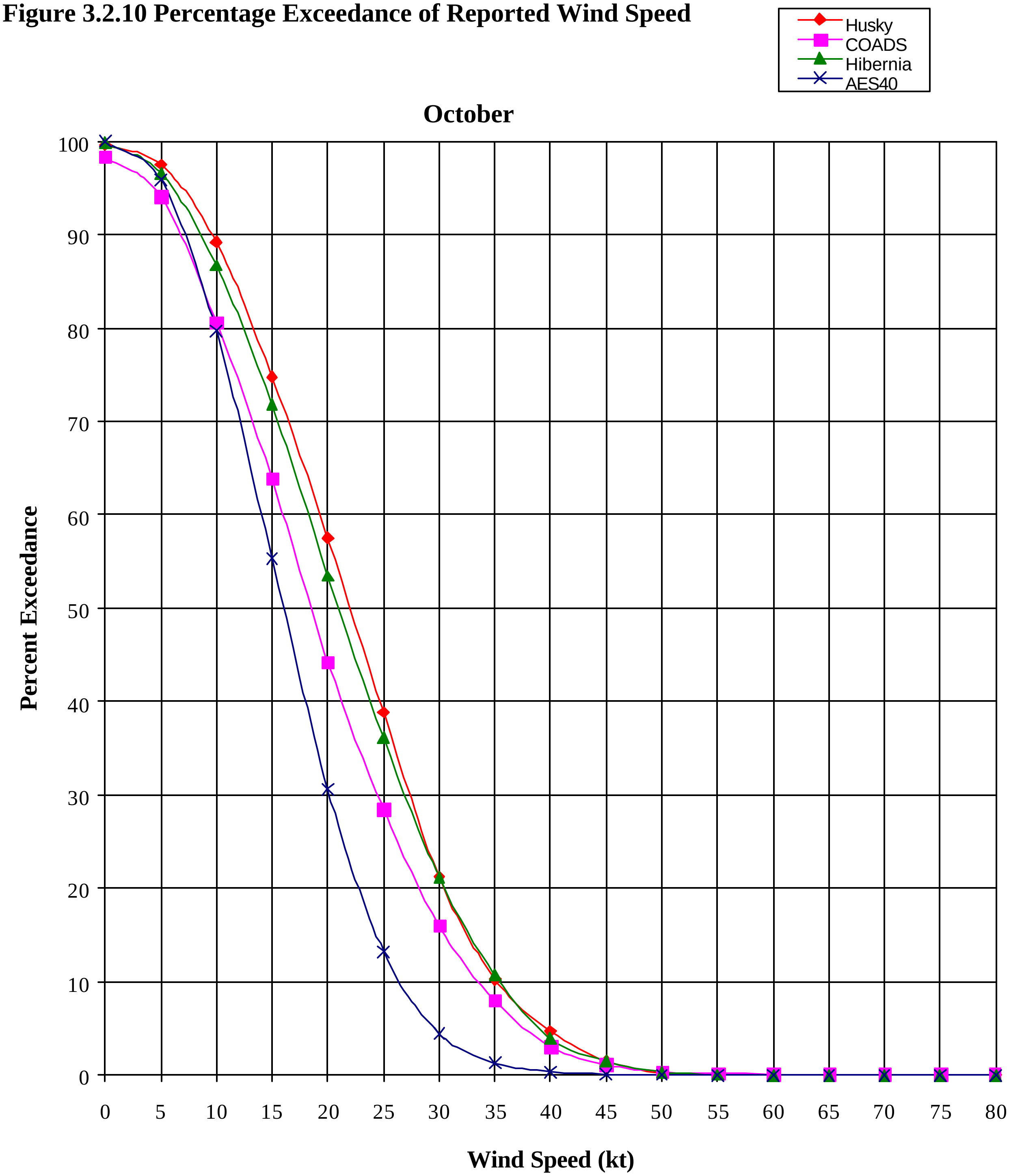
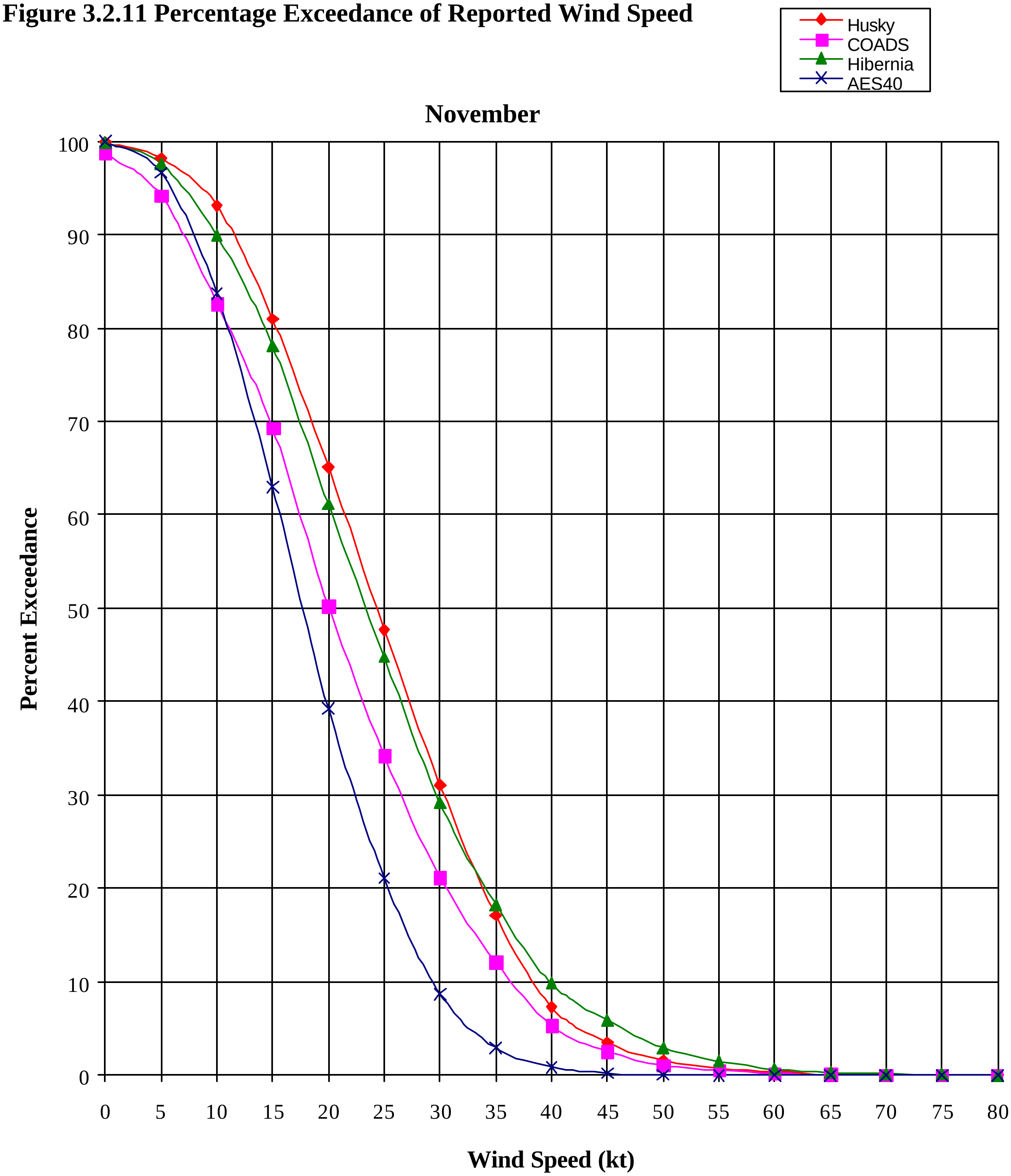
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.10 Percentage Exceedance of Reported Wind Speed



Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.11 Percentage Exceedance of Reported Wind Speed



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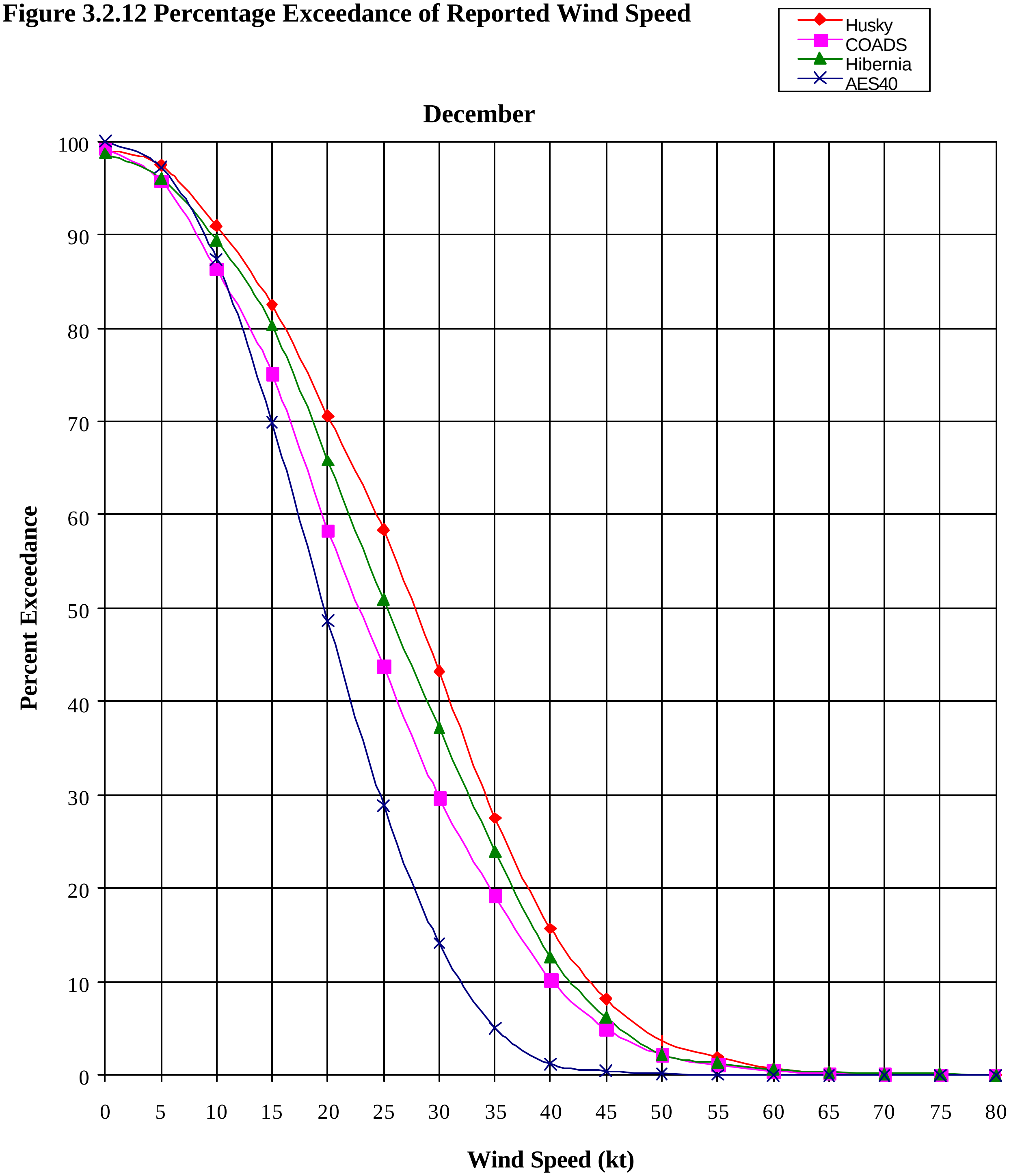
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 3.2.12 Percentage Exceedance of Reported Wind Speed

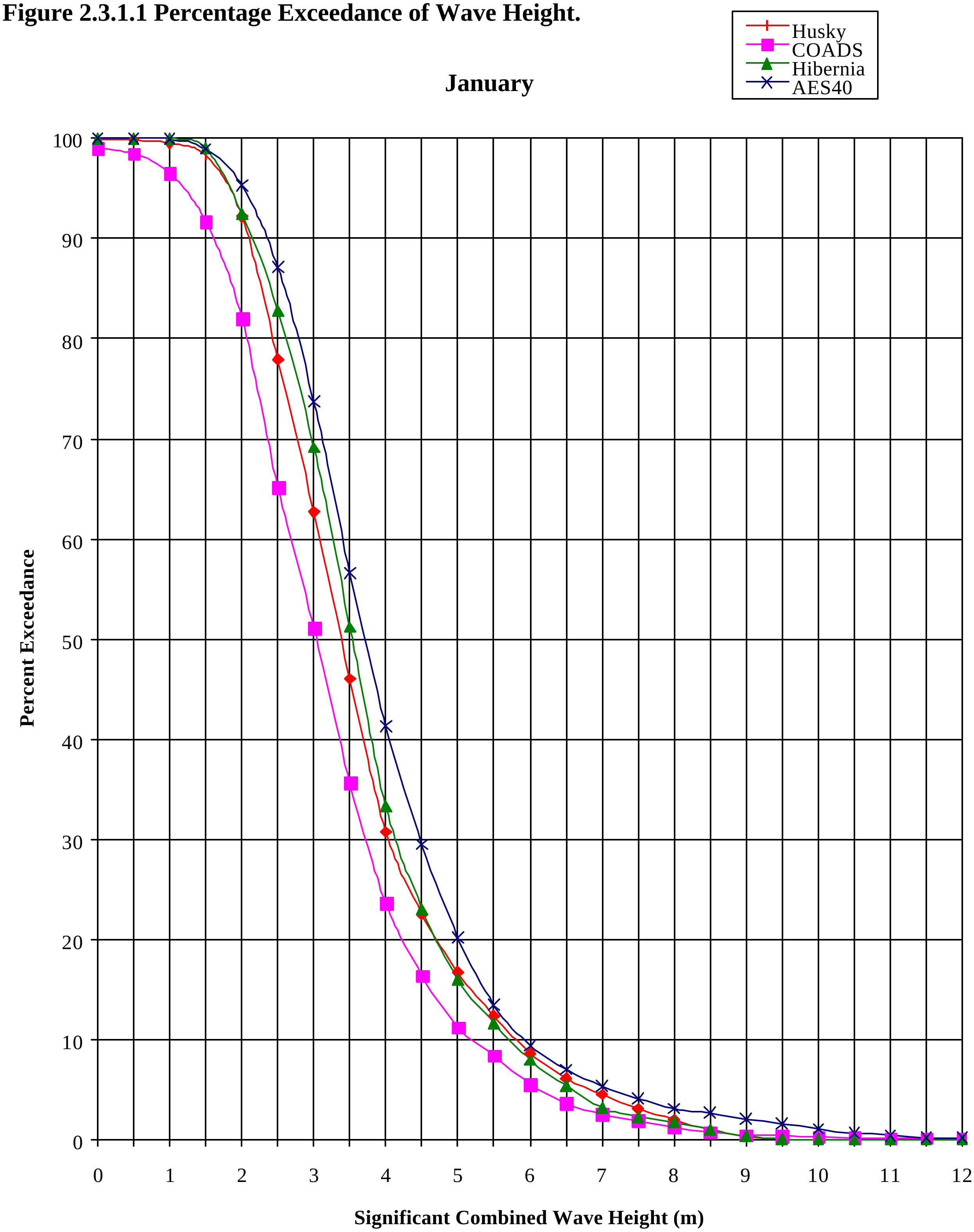


Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Appendix 2.C

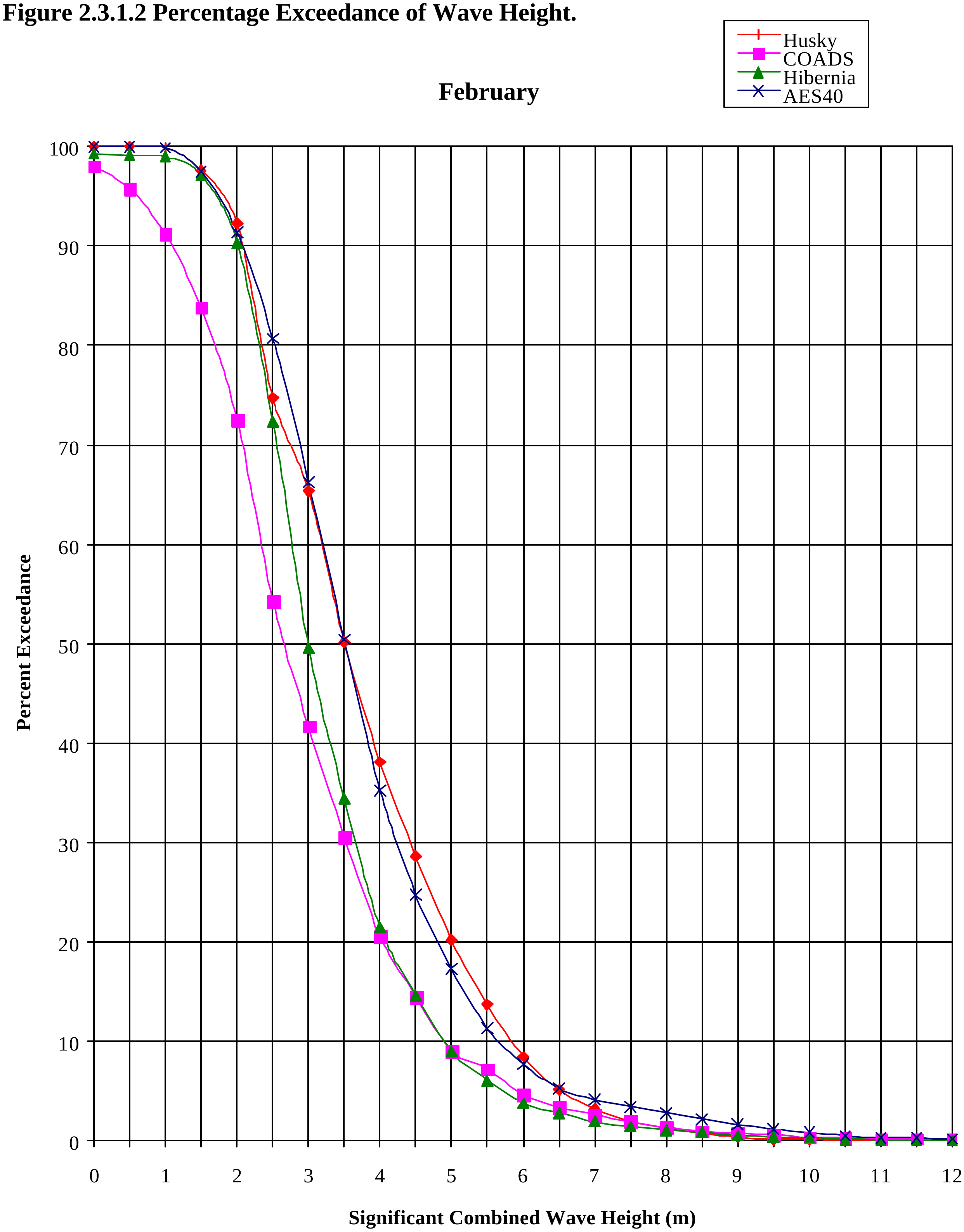
Wave Height Exceedance

Figure 2.3.1.1 Percentage Exceedance of Wave Height.



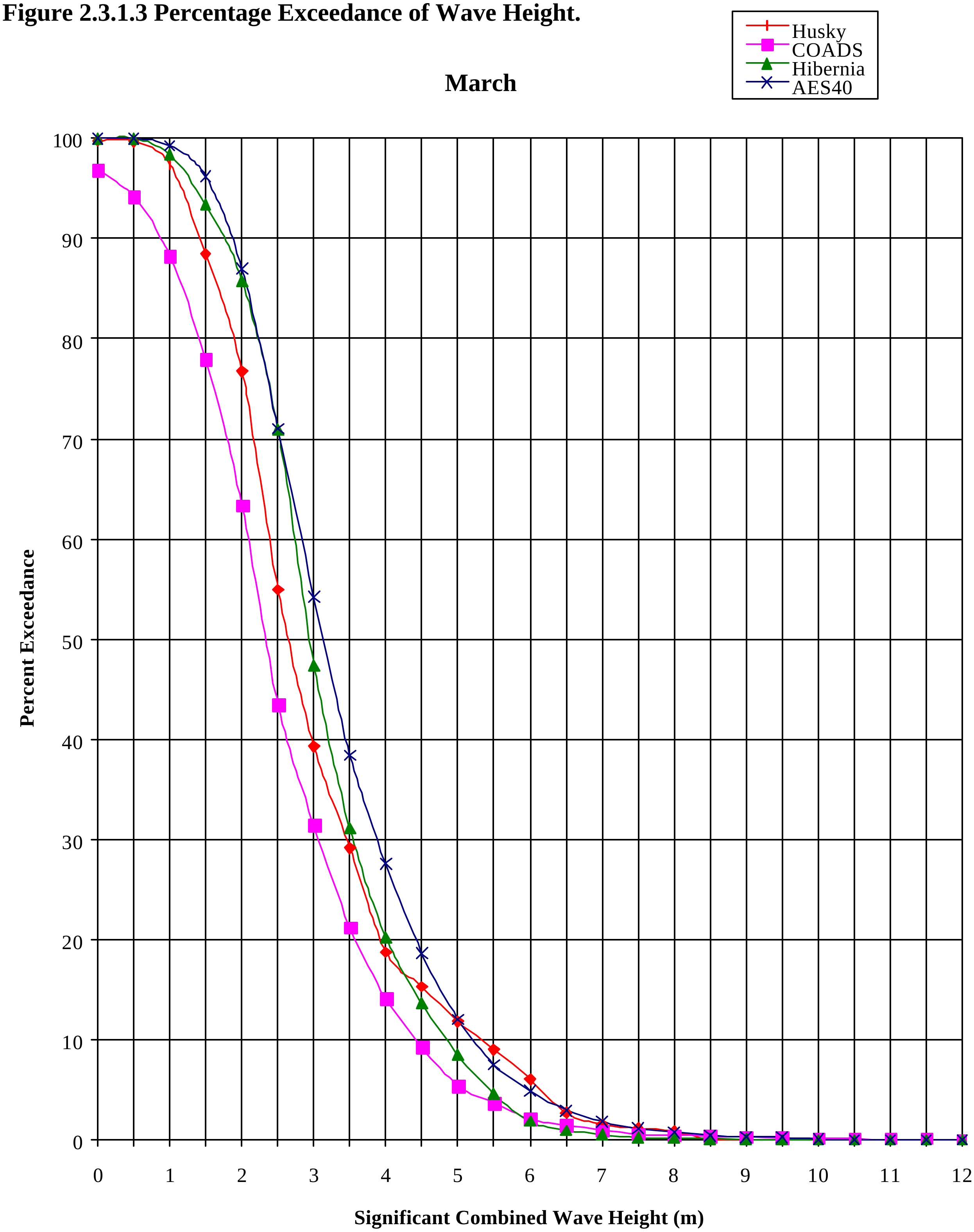
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.2 Percentage Exceedance of Wave Height.



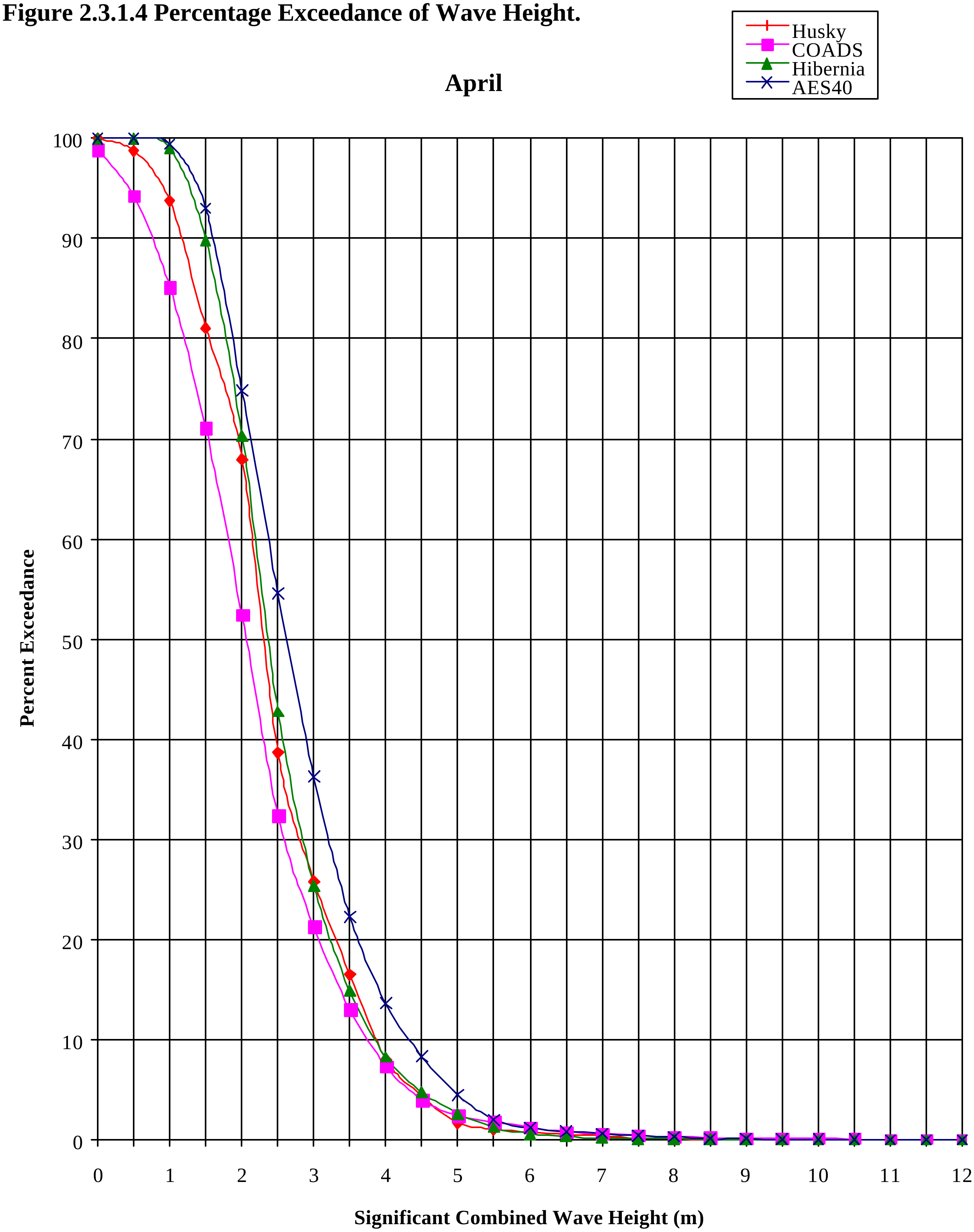
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.3 Percentage Exceedance of Wave Height.



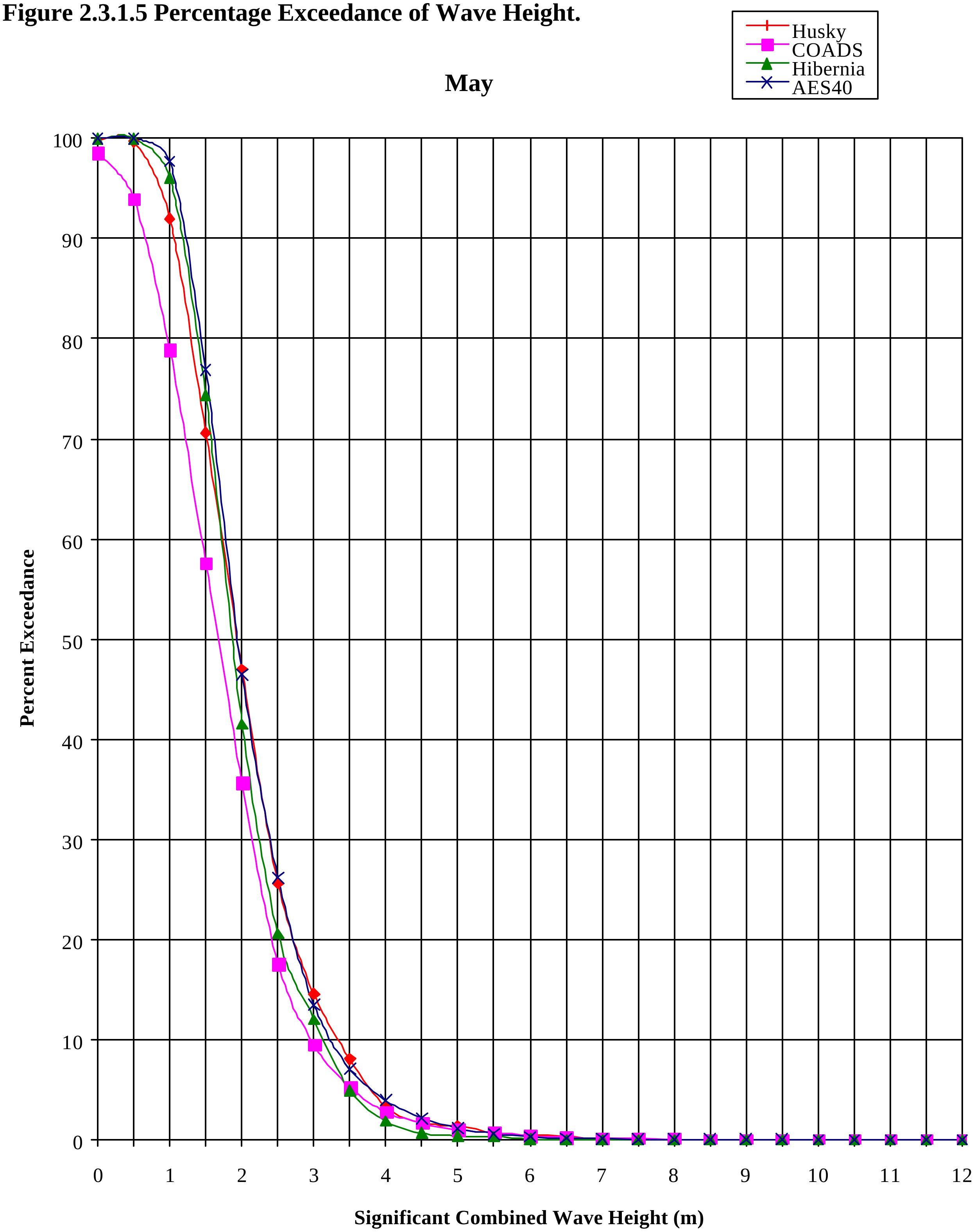
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.4 Percentage Exceedance of Wave Height.



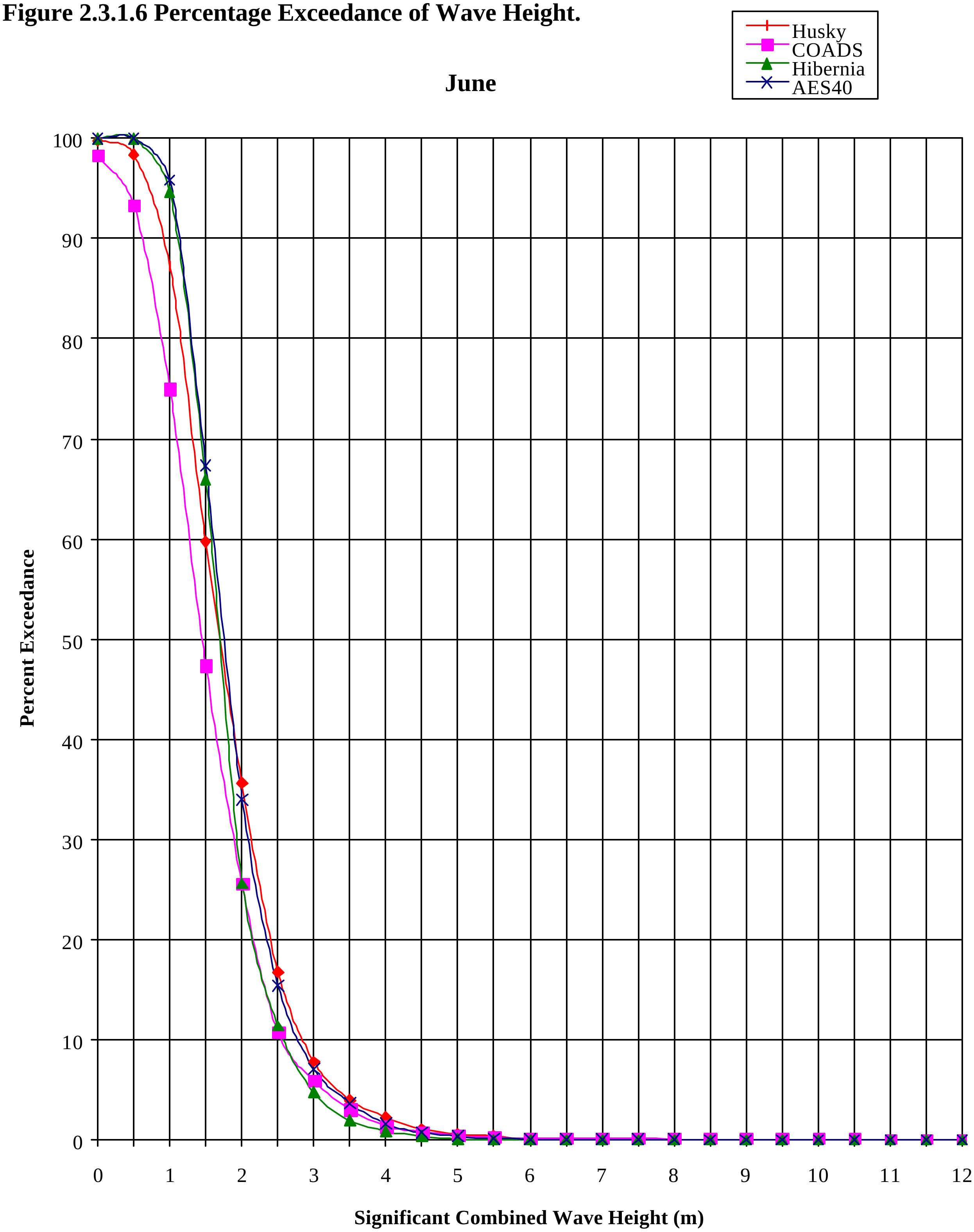
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.5 Percentage Exceedance of Wave Height.



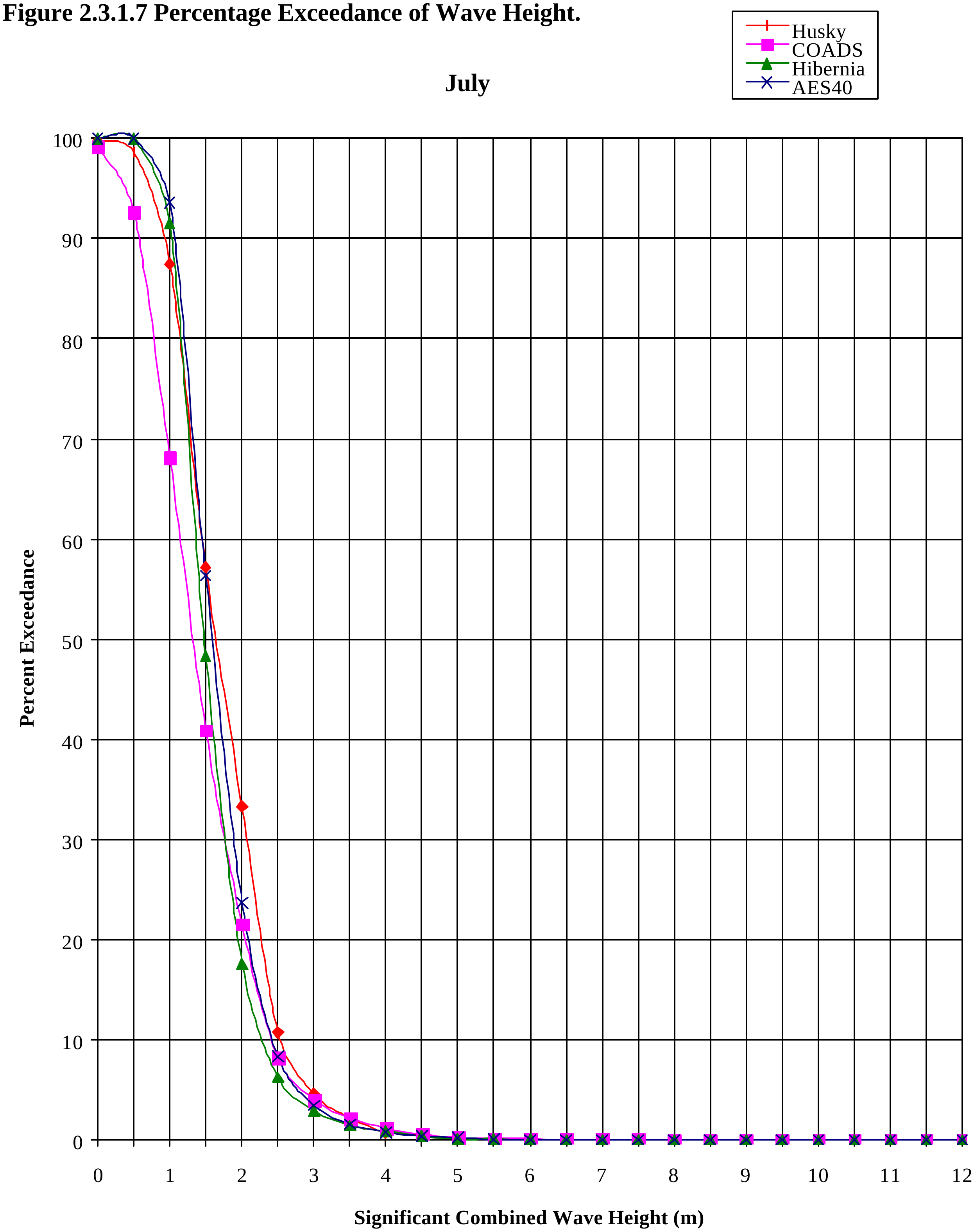
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.6 Percentage Exceedance of Wave Height.



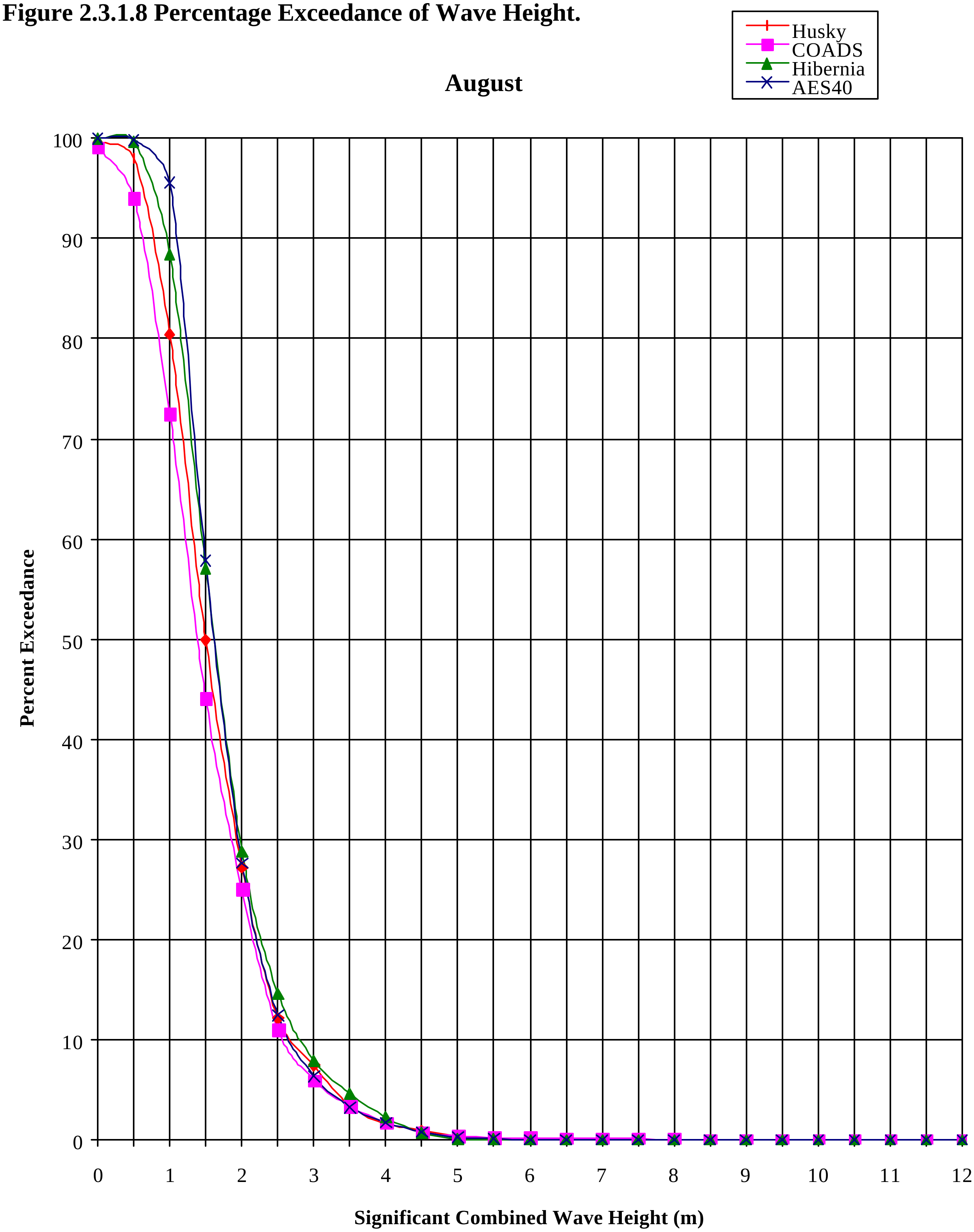
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.7 Percentage Exceedance of Wave Height.



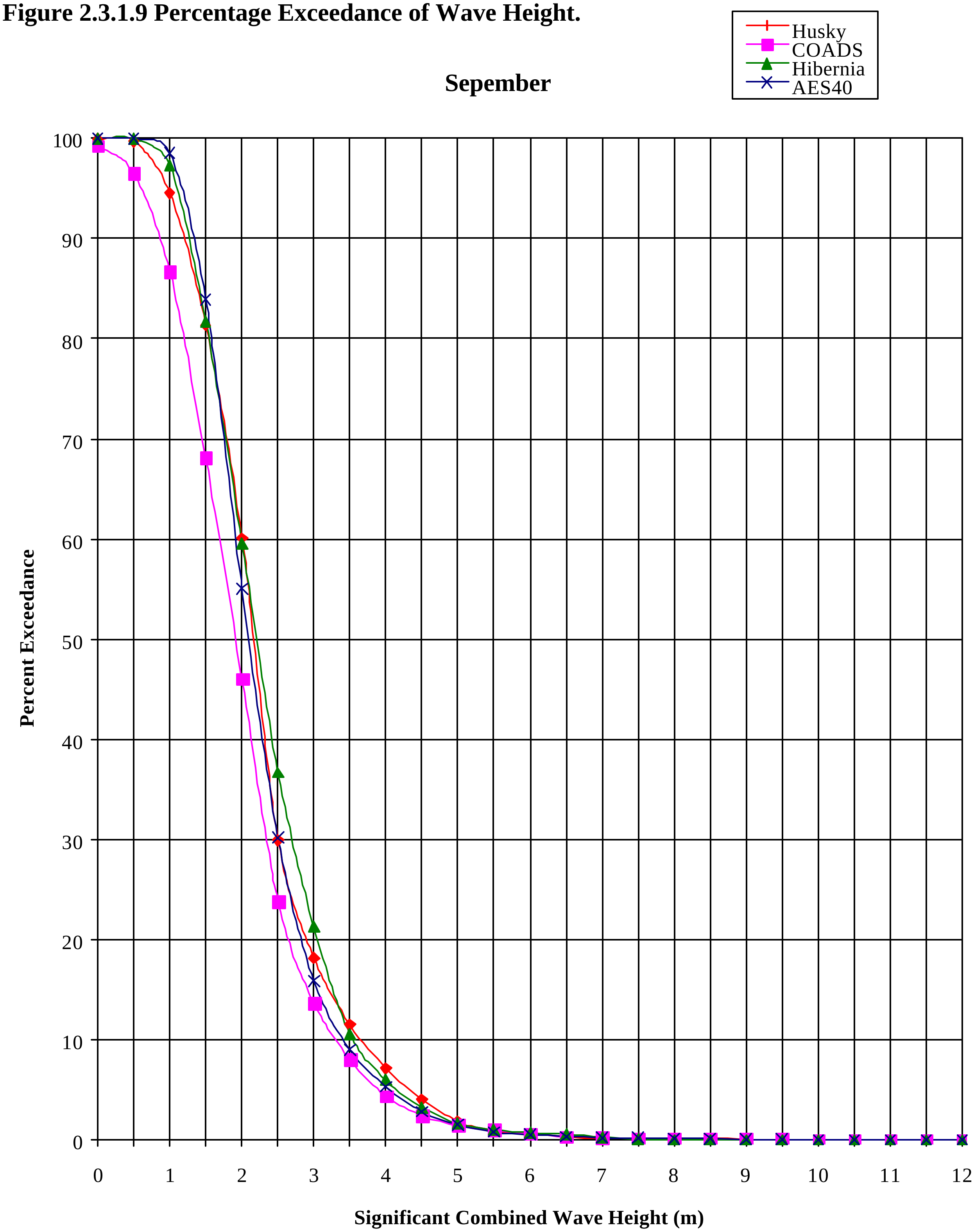
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.8 Percentage Exceedance of Wave Height.



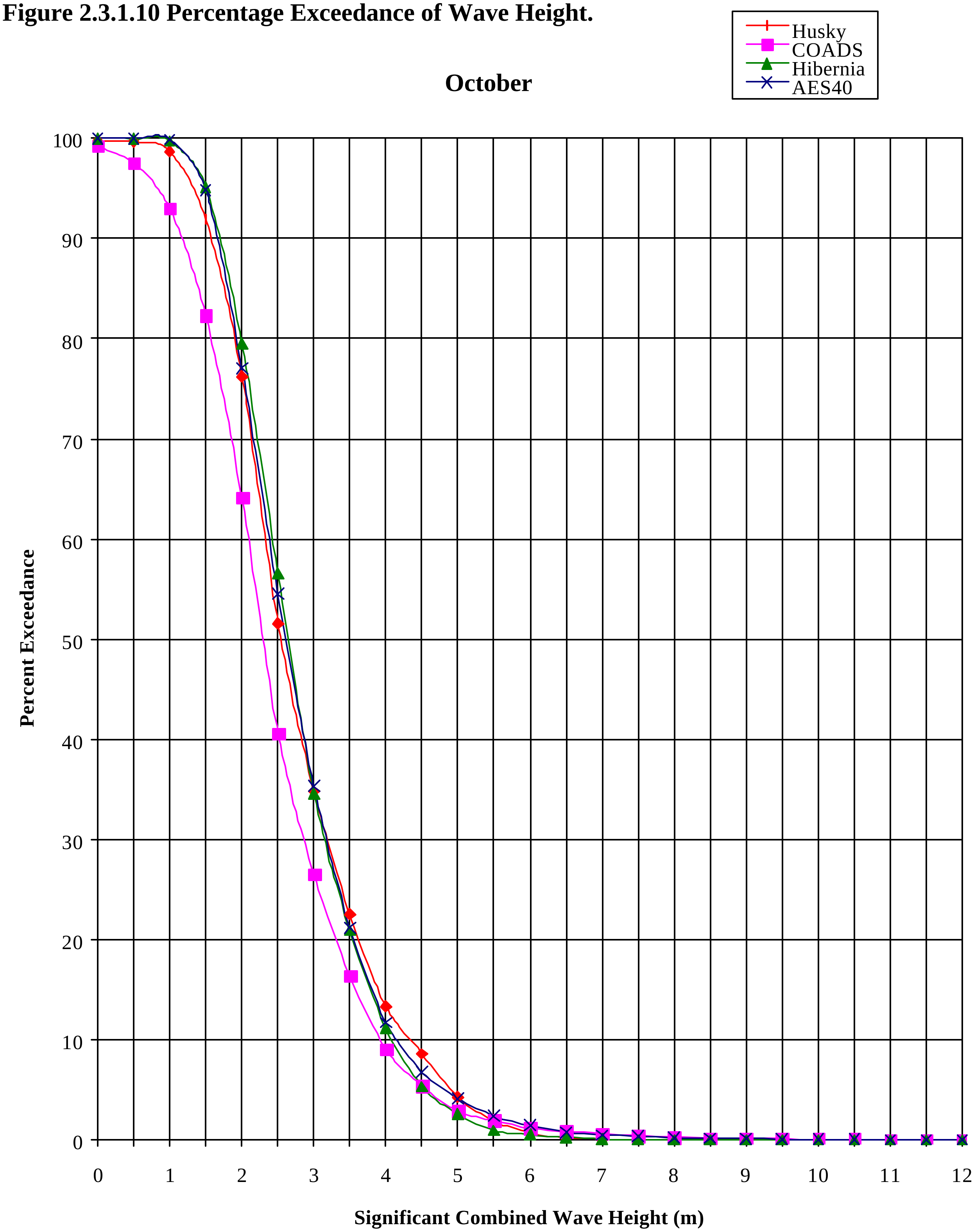
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.9 Percentage Exceedance of Wave Height.



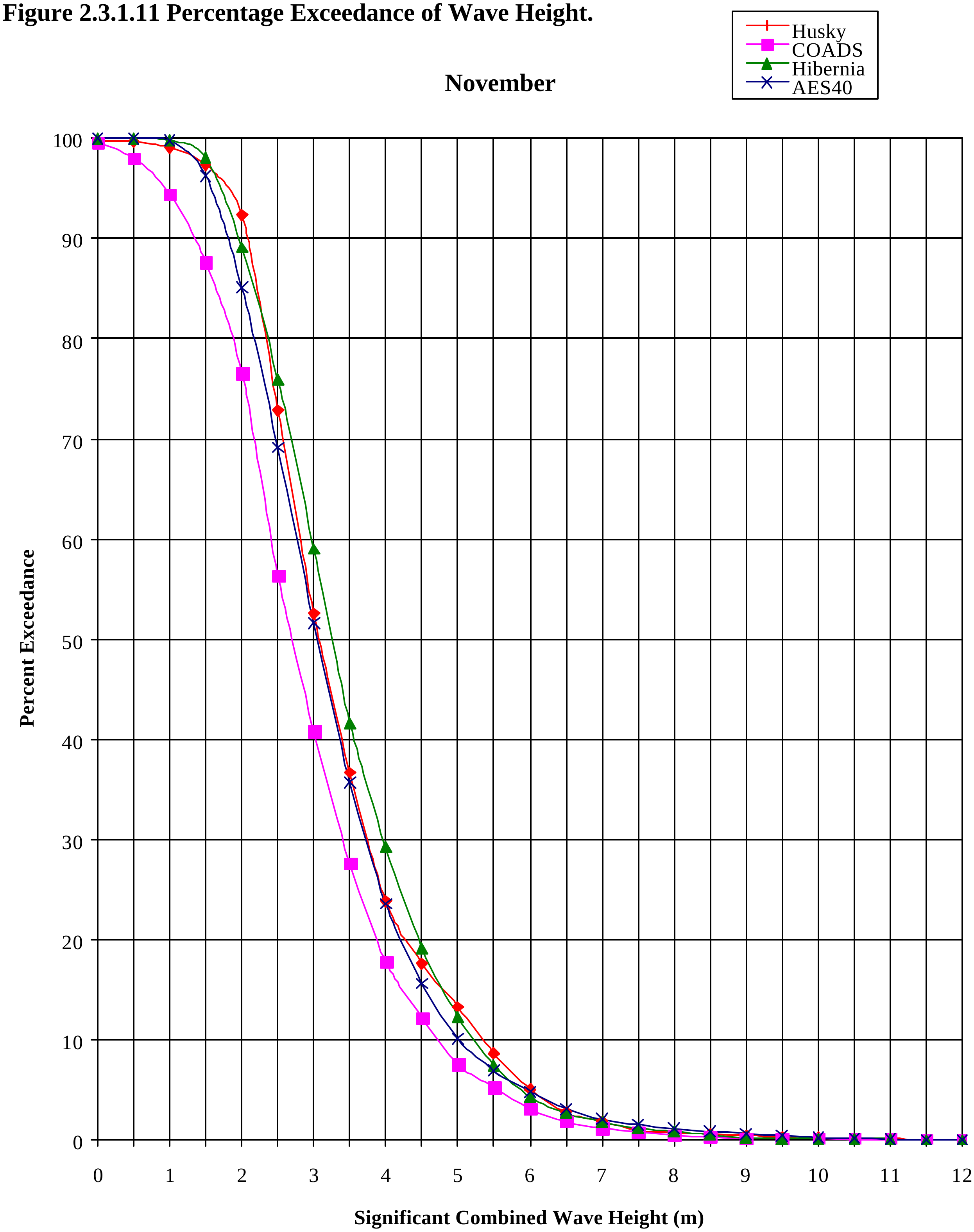
Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.10 Percentage Exceedance of Wave Height.



Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.11 Percentage Exceedance of Wave Height.



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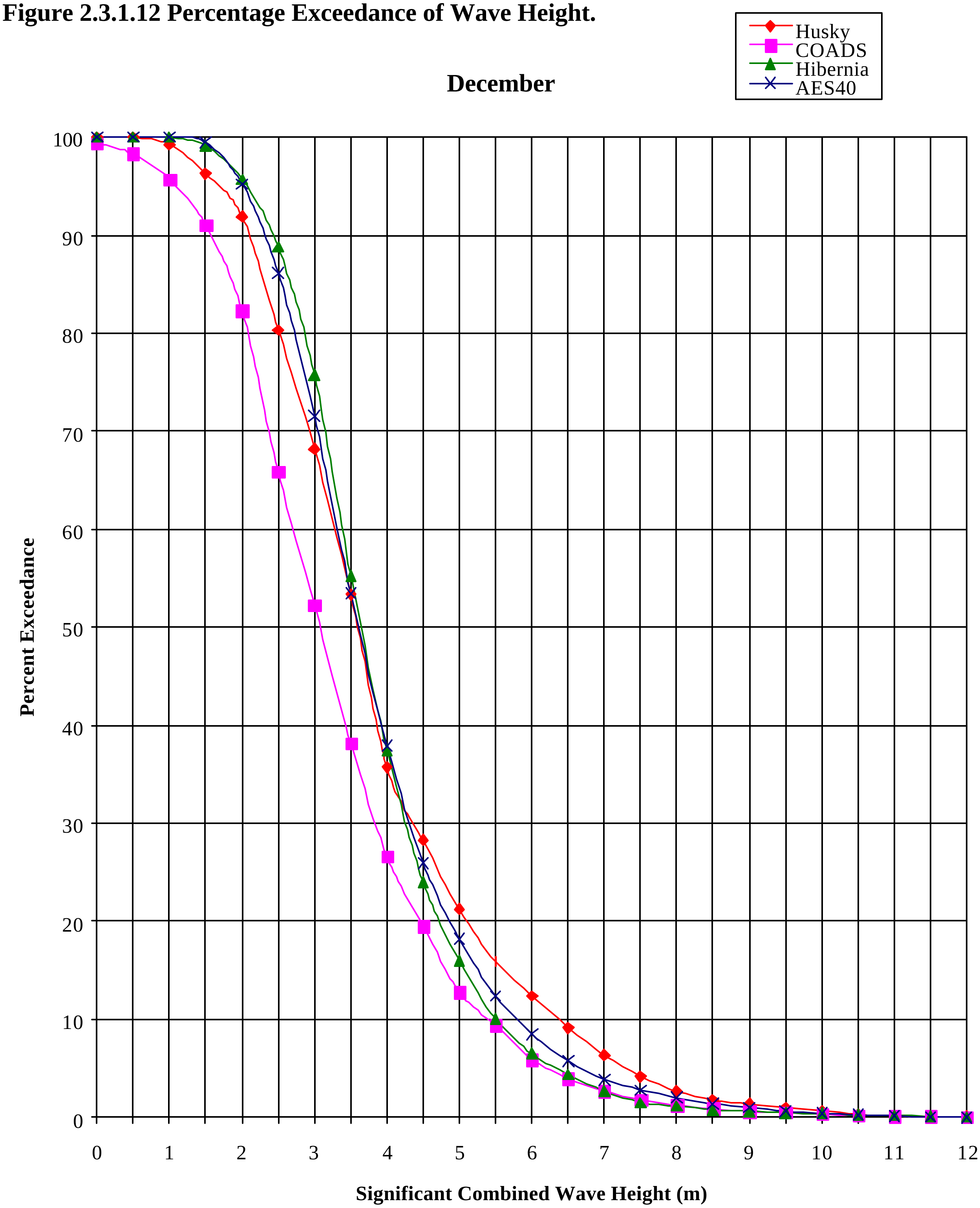
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Figure 2.3.1.12 Percentage Exceedance of Wave Height.



Data source: Husky: Husky/Bow Valley Grand Banks Environmental Data (Feb 84 to Aug 88)
Husky Oil Whiterose Environmental Data (Jun 99 to Oct 99)
COADS: COADS data for block 46-48N 47-49W, 1950 to 1995
Hibernia: Hibernia 9 year data series 1980 to 1988
AES40: AES40 grid point 5622 Data Lat 46.875N Long 48.3333W, 1958 to 1998

Appendix 4.A

Effects of Atmospheric Emissions on Health

Effects of Atmospheric Emissions on Health

Atmospheric emissions from the production system are relatively small (Section 4.3.2.13). As such, they will have a negligible effect on air quality on a regional scale. Ensuring that they have no significant effect on a local scale will be a specific goal during the project design phase. This will be achieved by ensuring that the flare, exhaust and vents are appropriately designed and located to prevent harmful exposure to people working on the vessel or in its vicinity.

The facility layout, as currently conceived, will be designed to optimize the separation between accommodation (where the majority of people on board spend the majority of their time) and the hydrocarbon process area. The hydrocarbon process area will be well ventilated because it is open to the atmosphere.

The installation design will include multiple independent heating, ventilation and air conditioning systems. These will be sufficiently separated to minimize the possibility of back flow of gases into non-hazardous areas through air intakes and will provide a selective emergency shutdown strategy. Air intakes into accommodations as well as process areas will be equipped with detection equipment to monitor for the presence of hazardous vapours.

In addition, any personnel working in an area that would pose a threat of exposure to harmful emissions will be required to use protective breathing apparatus. For example, any work in non-ventilated confined spaces will be subject to air quality monitoring under the project Safe Work Permit System.

Finally, as part of Husky Oil's normal hygiene program, operators on the FPSO will be monitored on a periodic basis to determine their exposure level and, if necessary, changes to equipment or operational practices will be implemented.

Appendix 8.A

Bridging Document Suggested Elements for the Drilling Phase

SUGGESTED ELEMENTS

DOCUMENTS

1 POLICY AND PROCEDURE (separate document)

1.1 Husky Oil Corporate Environmental Policy
1.2 Loss Control Management and Environmental Management Context
  1.2.1 Husky Oil Loss Control Management Plan
  1.2.2 White Rose Environmental Health & Safety Plan
  1.2.3 White Rose Environmental Management Systems
  1.2.4 Environmental Protection Plan
1.3 Roles and Responsibilities
1.4 Training and Education
1.5 Purpose
  1.5.1 Overview of Activities and Schedule
  1.5.2 Environmental Design Features
1.6 Organization
1.7 Maintenance of the Plan
  1.7.1 Responsibilities
  1.7.2 Initiating Revisions
  1.7.3 Revision Procedures
1.8 Revision Control Procedures

2 WASTE MANAGEMENT PLAN (separate document)

2.1 Environmental Orientation and Skills Competency
2.2 Chemical Management
  2.2.1 Environmental Concerns
  2.2.2 Appropriate Regulations
  2.2.3 Mitigation Procedures
  2.2.4 Relevant Documents and Management Plans
  2.2.5 Roles, Responsibilities and Authority
  2.2.6 Reporting
2.3 Solid Waste Disposal
  2.3.1 Environmental Concerns
  2.3.2 Appropriate Regulations
  2.3.3 Mitigation Procedures
  2.3.4 Relevant Documents and Management Plans
  2.3.5 Roles, Responsibilities and Authority
  2.3.6 Reporting
2.4 Sewage Treatment
  2.4.1 Environmental Concerns
  2.4.2 Appropriate Regulations

3 DRILLING WELL COMPLETIONS PROCEDCURES (separate document)

3.1 Drilling Mud Systems

- 3.1.1 Environmental Concerns
- 3.1.2 Appropriate Regulations/Guidelines
- 3.1.3 Mitigation Procedures
  - 3.1.3.1 Drilling Mud
  - 3.1.3.2 Mud Storage
  - 3.1.3.3 Mud Chemicals
  - 3.1.3.4 Mud Mixing
  - 3.1.3.5 Liquid Mud Storage System
  - 3.1.3.6 High-Pressure Mud Circulating System
  - 3.1.3.7 Active Mud Returns and Treatment
  - 3.1.3.8 Hazardous Zones

3.2 Drilling Mud Discharges

- 3.2.1 Environmental Concerns
  - 3.2.1.1 Water-Based Fluids
  - 3.2.1.2 Synthetic-Based Drilling Muds
- 3.2.2 Appropriate Regulations
- 3.2.3 Mitigation Procedures
  - 3.2.3.1 Procedures for Drilling Muds Use
  - 3.2.3.2 Procedures Prior To Shore And Offshore Transfer Of Synthetic-Based Mud
  - 3.2.3.3 Procedures for Shore and Offshore Receiving/Backloading Synthetic-Based Mud
  - 3.2.3.4 Procedures for Tripping Out the Hole
  - 3.2.3.5 Procedures for Tripping Into the Hole
  - 3.2.3.6 Procedures for Running and Cementing Casing
  - 3.2.3.7 Procedures Prior to and While Drilling or Circulating

3.3 Drilling Cuttings and Solids Control

- 3.3.1 Environmental Concerns
- 3.3.2 Appropriate Regulations
- 3.3.3 Mitigation Procedures

3.4 Deck Drainage

- 3.4.1 Closed Hydrocarbon Drainage System
  - 3.4.1.1 Environmental Concerns
  - 3.4.1.2 Appropriate Regulations
  - 3.4.1.3 Mitigation Procedures
- 3.4.2 Open Drainage System and Sump Skimmer
  - 3.4.2.1 Environmental Concerns
  - 3.4.2.2 Appropriate Regulations
  - 3.4.2.3 Mitigation Procedures

3.5 Well Completions and Well Testing

- 3.5.1 Well Completion Fluids
- 3.5.2 Liner Cleaning
- 3.5.3 Removal of Fluids and Cuttings
- 3.5.4 Clean-up and Well Testing

4 PLATFORM SUPPLY AND SERVICES PROCEDURES (separate document)

4.1 Platform

4.2 Helicopters

- 4.2.1 Fueling and Maintenance
  - 4.2.1.1 Environmental Concerns
  - 4.2.1.2 Appropriate Regulations
  - 4.2.1.3 Mitigation Procedures
- 4.2.2 Routing Activities
  - 4.2.2.1 Environmental Concerns
  - 4.2.2.2 Appropriate Regulations
  - 4.2.2.3 Mitigation Procedures

4.3 Supply Vessels

- 4.3.1 Traffic (including routing)
  - 4.3.1.1 Environmental Concerns
  - 4.3.1.2 Appropriate Regulations
  - 4.3.1.3 Mitigation Procedures
- 4.3.2 Solid Wastes and Sewage Disposal
  - 4.3.2.1 Environmental Concerns
  - 4.3.2.2 Appropriate Regulations
  - 4.3.2.3 Mitigation Procedures
- 4.3.3 Bilge Drainage
  - 4.3.3.1 Environmental Concerns
  - 4.3.3.2 Appropriate Regulations
  - 4.3.3.3 Mitigation Procedures

5 ENVIRONMENTAL COMPLIANCE MONITORING [separate document]

6 ENVIRONMENTAL EFFECTS MONITORING [separate document]

7 CONTINGENCY PLANS FOR EMERGENCIES [separate document(s)]

9 FISHING INDUSTRY AGREEMENTS [separate document]

WHITE ROSE OILFIELD
COMPREHENSIVE STUDY

PART TWO
SOCIO-ECONOMIC IMPACT STATEMENT

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1 INTRODUCTION

1.1 SOCIO-ECONOMIC IMPACT STATEMENT FOCUS

This Socio-Economic Impact Statement (SEIS) discusses the socio-economic effects of the White Rose offshore oilfield development project (hereafter referred to as the "Project"). The document has been prepared in accordance with the requirements of both the *Canadian Environmental Assessment Act* (CEAA), and the Canada-Newfoundland Offshore Petroleum Board (C-NOPB) Development Application Guidelines (DA Guidelines) (C-NOPB 1988). The SEIS focuses on three main issue areas which reflect the primary concerns of the public and the issue scoping document determined for the project under the CEAA and the DA Guidelines:

- business and employment;
- community social and physical infrastructure and services; and
- fisheries.

The geographic scope of the analysis is primarily provincial, with those areas most likely to experience direct effects from the Project examined in greater detail as outlined in Section 2.1. The temporal scope of the Project considers activities from the initial development phase, through installation and operations, decommissioning and abandonment. The main socio-economic effects are expected to be associated with short-term field development activities, including some fabrication and construction, and long-term operations activities.

The preferred production system for the development of the White Rose oilfield is a ship-shaped floating production, storage and offloading (FPSO) vessel. An alternative is to use a semi-submersible production system and an offshore storage vessel. While each of these has its own technical requirements, the socio-economic implications of both options are essentially the same in terms of their types of effects, their magnitude and their geographic and temporal implications. Hence, the assessment which follows does not consider the effects of preferred and alternative options separately, but as one. A full discussion of the concept selection rationale, as well as the benefits associated with the preferred and alternative options will be provided in the Development Plan and Canada-Newfoundland Benefits Plan to be provided to the C-NOPB under the DA Guidelines.

1.2 THE NEWFOUNDLAND OIL INDUSTRY

Preparations for the development of the White Rose oilfield is the latest step in the growth and maturing of Newfoundland and Labrador's oil industry. There has been offshore activity in the province's waters since the mid-1960s, but the last decade has seen an acceleration in its pace and scale. In 1990, Hibernia moved forward as the province's first development project and then, in 1997, its first producing field. The Terra Nova project moved into development in 1998, representing the initial use of floating production technology offshore Newfoundland, and it will come into production in early 2001. Other field development projects are under consideration, and there has been a recent increase in exploration, with Husky Oil Operations Limited ("Husky Oil") and other operators moving to sustained, multi-phase (that is, exploration, delineation, development and production) activity in the province's waters.

The economic and social benefits from the industry are already substantial and widely-spread. In 1999, offshore-related activity and associated spin-offs accounted for over 10 percent of provincial Gross Domestic Product (GDP) and 2.6 percent of employment (Department of Finance 2000a). Study of Hibernia operations in 1998 (HMDC 1999) indicates that expenditures on this one project totalled $299 million, with approximately $191 million (64 percent) being spent in Newfoundland. Wages, salaries and employee benefits, at $68.8 million, were a major component of these expenditures, with Hibernia having 705 steady-state employees, 583 (83 percent) of them Newfoundlanders (including returned migrants) (HMDC 1999). Furthermore, a wide range of Newfoundland companies worked directly on Hibernia operations. In addition to the Alliance partners and major contractors, 189 Newfoundland companies were issued purchase orders worth a total of $8.5 million.

There is also a range of secondary effects as project expenditures circulate through the economy. During 1998, as a result of this single production project, Newfoundland's GDP was $626 million higher (5.7 percent of provincial GDP), its personal income was $168 million (1.7 percent) higher; consumer spending on goods and services was $124 million (1.7 percent) higher, total employment was 3,100 greater, the unemployment rate was half of a percentage point lower, and the total population was 5,000 greater, due to reduced out-migration and increased in-migration (HMDC 1999).

The Terra Nova project has also already generated substantial provincial economic benefits. Spending on Terra Nova in 1999 was approximately $800 million. Onshore activities have included project management and procurement, subsea template fabrication, topsides module fabrication and expansion of the quay at Bull Arm. In addition, offshore activity included the excavation of five glory holes and the commencement of development drilling (Department of Finance 2000a).

Commissioning of the Terra Nova FPSO at Bull Arm is now underway. Peak employment at the yard during construction has been approximately 950. This is expected to increase to approximately 1,300 before work is completed in late 2000.

Husky Oil exploration activity has already made a more modest, but nevertheless important, contribution to the provincial economy. For example, during 1999, Husky Oil and its major contractors employed 529 people, of whom 498 (94 percent) were Canadian and 455 (86 percent) Newfoundland residents. This provided 2,218 work-months of employment, of which 1,531 went to Newfoundlanders and 307 to other Canadians. It should be noted that these figures exceeded, in both absolute and relative terms, commitments Husky Oil made in its 1999 Benefits Plan.

In terms of expenditures, Husky Oil's 1999 exploration program cost a total of $107 million and provided work for a wide range of Newfoundland-based companies. Approximately $2.5 million was spent on education and training and $84,000 on research and development in support of the program (Husky Oil 2000a).

This new industry has clearly already made, and will continue to make, a very important contribution to the economy and society of Newfoundland and Labrador. Local individuals, companies and institutions are developing skills and capabilities that, if globally competitive, will allow them to undertake the great majority of work on White Rose and other projects in Newfoundland. Furthermore, these new capabilities and ambitions are not just applicable to the oil industry or in Newfoundland or Canada. Oil activity to date has helped make local firms and individuals highly competitive and get work on other petroleum projects, and on projects in other industries, locally, nationally or internationally. Similarly, while the new oil industry-related research, development, education and training infrastructure was put in place to support local oil activity, local firms and individuals using this infrastructure can undertake work for clients outside the Province and outside the oil industry, further developing and diversifying the economy.

Furthermore, and notwithstanding concerns expressed during the 1980s, the development of this new industry has not been accompanied by large-scale in-migration or significant negative social and economic effects on the fishery, communities, families and the Newfoundland way of life. Rather, it has had a range of positive consequences, directly through the creation of employment and business, and indirectly through multiplier effects and by increasing the province's tax base. The White Rose oilfield development, smaller but similar in approach to Terra Nova, will continue this trend.

The proposed White Rose project is the next major stage in the development of this industry. If approved, it will be the third oilfield in production. Following on Terra Nova, it may further develop the capabilities of companies and individuals working on that project. In particular, it will allow further development of internationally competitive capabilities related to floating production systems, sub-sea completions and directional drilling, which present major international employment and business opportunities. Furthermore, as the first project subject to the province's generic royalty regime, it will contribute significant direct, as well as indirect, resource revenues. Overall, White Rose will be a major net contributor to the economic and social development of Newfoundland and Labrador.

2 ASSESSMENT SCOPE AND METHODOLOGY

This chapter describes the geographic scope for the SEIS and the methods used to assess potential effects.

2.1 GEOGRAPHIC SCOPE

The location of Project phase activities is fundamental to the assessment of socio-economic effects. The locations for long-term operations phase activities are more easily identified than those for short-term development phase construction, fabrication or assembly work. For this reason, the certainty with respect to which areas will be affected by the Project, and the degree to which each of those areas will be affected, varies.

During the 12 to 14-year lifespan of the oilfield, the St. John's area will be the administrative, business, technical and transportation centre for the Project. Anticipated effects will be wide-ranging and ongoing. The effects will primarily beneficial, involving the creation of considerable employment and business. Given the nature of the proposed production system, the type of effects expected in the St. John's area during this phase are likely to be similar, but somewhat less than those associated with Terra Nova.

Many of the short-term, construction/installation phase activities are not necessarily tied to specific locations. Husky Oil is committed to a process that will seek to maximize benefits to Newfoundland and Labrador on a competitive basis, but the construction and fabrication of production system components for either the FPSO vessel or semi-submersible options is likely to involve some contractors elsewhere in Canada and in other countries. Until Project contracts are awarded, the final pattern of effects will not be known.

Within Newfoundland and Labrador, experience with the Hibernia and Terra Nova projects has, however, helped establish a precedent for the likely geographic pattern of activity. While a number of locations could be involved in fabrication, maintenance, inspection and repair functions, those most closely involved with these earlier projects have been chosen for more detailed assessment. This allows for comparisons with these projects and an analysis of potential cumulative effects. The areas most likely to experience the main effects of the Project are described in the following sections.

2.1.1 St. John's Area

The St. John's area will be the administrative centre, supply and service centre and personnel transportation hub for White Rose, as is the case for the Hibernia and Terra Nova projects. Supply-base and helicopter operations will be located in the St. John's area, as might some fabrication activity. The geographic area for any effects associated with these activities is taken as the St. John's Census Metropolitan Area (CMA) (Figure 2.1-1).

The CMA is an official statistical unit defined as the region from within which significant numbers of people travel to work daily. The CMA was one of the areas used in the Hibernia and Terra Nova assessments, allowing comparisons to be made with those projects. Furthermore, any cumulative effects of these and other projects can be determined for this area.

2.1.2 Isthmus of Avalon Area

The Bull Arm site on Trinity Bay was developed as the construction and fabrication facility for the Hibernia project. Since then, it has been used for fabrication of topside modules and components for the Terra Nova project, albeit involving lower levels of activity. Depending on the outcome of competitive bidding processes, the site could be similarly used for component fabrication and outfitting for either of the proposed White Rose FPSO or semi-submersible production facility options.

As with the Hibernia and Terra Nova project assessments, the main local employment and community effects of activity at Bull Arm are assumed to fall within the daily commuting range of the site. While some workers may travel considerably greater distances, the primary commuting zone is assumed to approximate a 50-km zone centred on Bull Arm. For data collection purposes, the boundary of the study area corresponds to those Consolidated Census Sub-Divisions (CCSDs) that approximate the 50-km zone (Figure 2.1-2). The area is the same as that used for the Hibernia and Terra Nova project assessments; this facilitates comparison of individual project effects together with any cumulative effects. Not all data regions conform to this study area. Where this is the case, approximations are made, and the differences noted.

Figure 2.1-1   St. John's Census Metropolitan Area

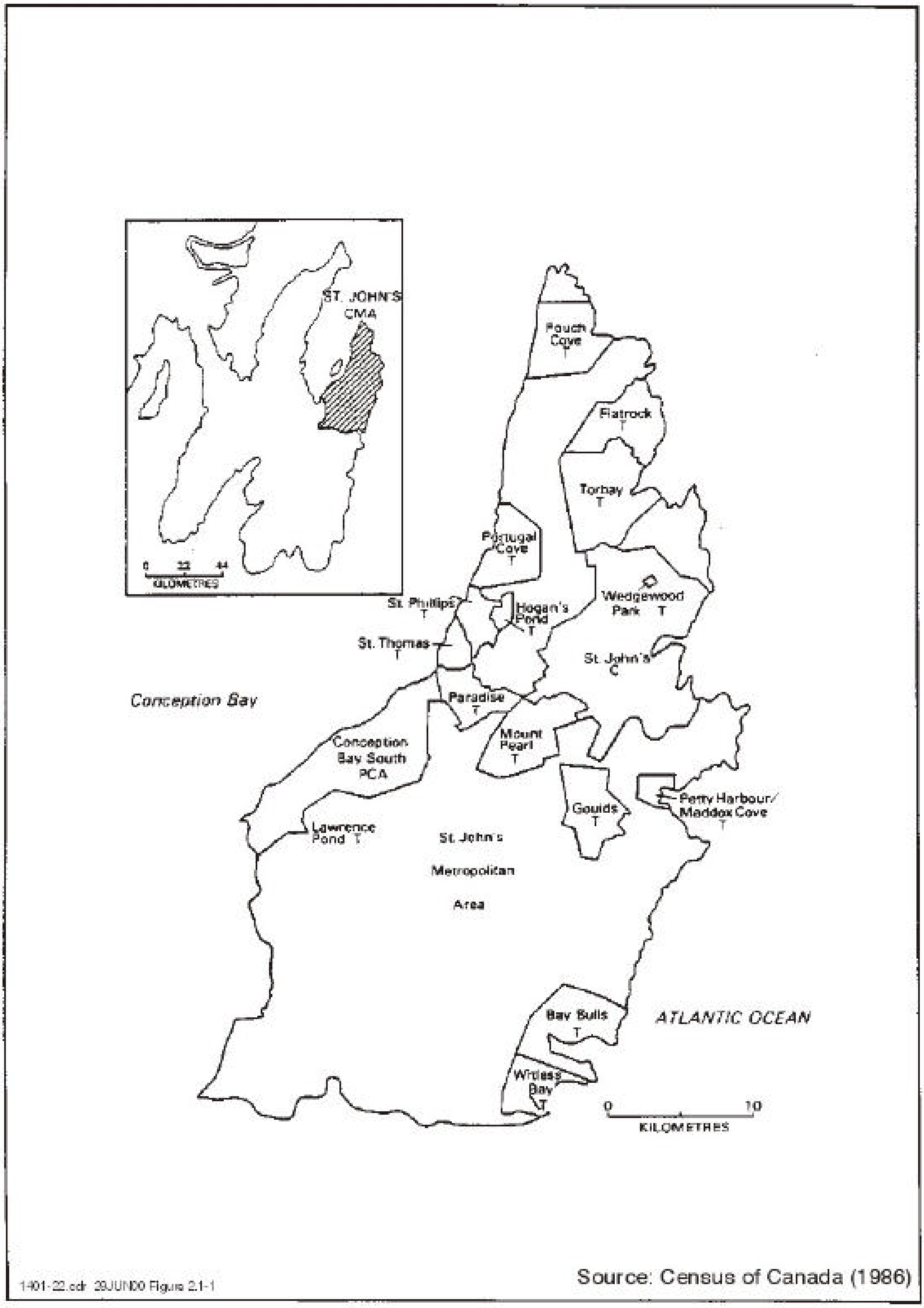
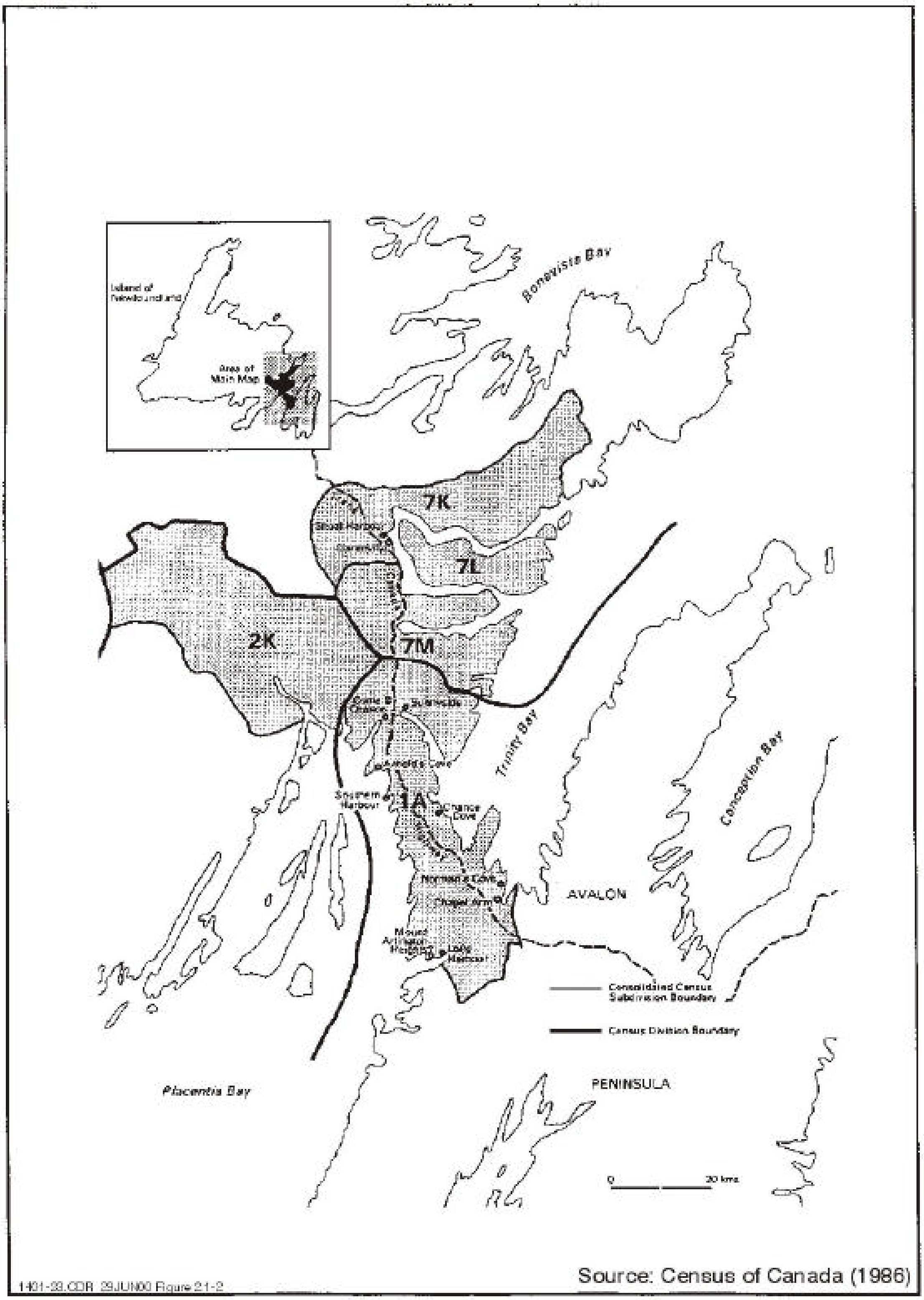


Figure 2.1-2 Area Within 50-km Radius of Bull Arm



2.1.3 Marystown Area

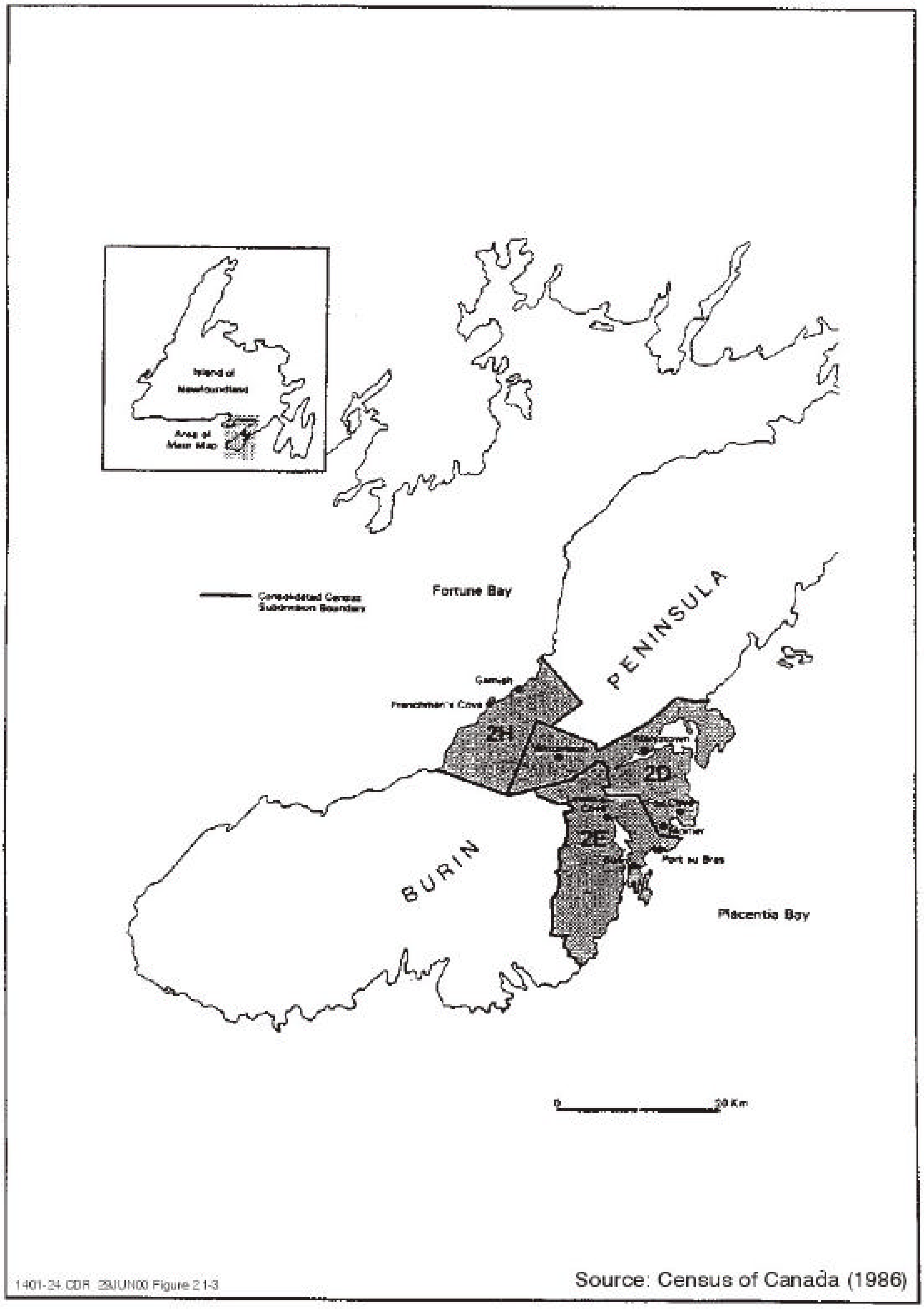
Marystown has the largest shipbuilding and repair facility in the Province. In addition, the Cow Head offshore fabrication and repair facility provides the capability for fabrication, repair and maintenance of a range of offshore floating structures. A number of components for the Hibernia project were fabricated here, rig refitting was carried out for the Terra Nova project, and tugs were built for the Newfoundland Transshipment Terminal. These types of work suggest the area could also see White Rose Project activity.

The study area is also based on a nominal 50-km commuting zone from Marystown and includes all CCSDs that fall within this radius (Figure 2.1-3). The same study area was also adopted for the Hibernia and Terra Nova project assessments, and the same approximations are made where data for some variables do not match the selected area.

2.1.4 Other Areas

Other communities and geographic areas are referred to as relevant. For example, in Chapter 7, which looks at the effects on the commercial fishery, fisheries activity in the North Atlantic Fisheries Organization (NAFO) Areas 3L, 3M, 3N, 3O and other more specific statistical unit areas (for example, 3Lt), adjacent to the White Rose oilfield are discussed.

Figure 2.1-3 Area Within 50-km Radius of Marystown



Source: Census of Canada (1986)

2.2 ASSESSMENT METHODOLOGY

This SEIS adopts a standard assessment approach designed to satisfy of the terms of reference for the assessment, while giving particular attention to those socio-economic issues identified as being of greatest interest and building on the experience of other Newfoundland offshore projects. The assessment approach is based on the identification of Valued Environmental Components (VECs) and is described in the following sections.

2.2.1 Selection of Valued Environmental Components

The VEC approach offers the advantage of ensuring that:

- the focus of the assessment is the key issues identified by those most likely to be affected by the Project; and
- the pathways and interactions among VECs and their components and characteristics can be identified and their effects analyzed.

The socio-economic VECs identified through the issues scoping process described previously, and which form the basis for this assessment are:

- employment and business;
- community infrastructure - including
  - social infrastructure and services (health, education, social services, policing, etc.),
  - physical infrastructure (air, highway, port, housing, land, etc.); and
- fisheries.

Employment and business are valued by individuals who may benefit directly or indirectly from:

- work in its own right;
- changes in incomes and standards of living; and
- development of skills and expertise.

New projects are generally beneficial from an economic perspective insofar as more people are employed, and successive rounds of employee and business expenditures generate employment and income multiplier effects in the local and provincial economies. However, particular socio-economic effects can be both positive and negative where different segments of society are differentially affected.

The employment and business effects of the Project are greatly influenced by the Husky Oil White Rose Canada-Newfoundland Benefits principles and practices, which will be outlined in the Canada-Newfoundland Benefits Plan to be provided to the C-NOPB.

Local residents value infrastructure and services insofar as their quality and capacity in a community contribute to the overall standard of living and quality of life.

Project employment and spending may result in increased incomes and lifestyle changes, or encourage the movement of people into particular communities, leading to increased demands on services and infrastructure. Where those components are operating at or beyond designed capacity, any incremental demand will further negatively affect the quality and quantity of services available to local residents. Where there is underused capacity in the system, increased demands may have no significant effects or increase the viability of particular services and infrastructure.

Both individuals and society value the fisheries because:

- historically, they have played a dominant role in the economy of Newfoundland and Labrador; and
- socially, they have helped define the character of much of Newfoundland, its people and its communities; for many, fishing is not merely a job, it is a way of life.

The closure of the groundfish fishery in 1992 sent significant warnings to those who fish, regulators, companies and others about the vulnerability of the fishery to human activities. Given the economic and social importance attached to the fishery, any action that has the potential to affect the sector will continue to require close scrutiny by the designated regulatory agencies.

The selection of VECs has been strongly influenced by experience of past offshore oil projects in Newfoundland. The Hibernia and Terra Nova projects have provided a significant level of understanding of the types and nature of the socio-economic effects of offshore development in Newfoundland and on specific communities. Many of the concerns that were raised in the 1980s, at the time the DA Guidelines (C-NOPB 1988) were being drafted and before the Hibernia project started, have since been shown to be of minor significance, while others have become of greater significance to the public and the regulators.

For example, studies of the effects of the Hibernia construction project (Storey et al 1996; HMDC 1996a; Jones 1998) indicate that people's concerns about implications of the project did not materialize and, as a consequence, changed over the life of the project (Table 2.2-1 and 2.2-2). More than half of the Isthmus area residents surveyed anticipated significant increases in crime associated with the Hibernia construction project before it was approved (1985 data). However, experience with the project virtually eliminated these concerns, such that by 1996 only 2.6 percent of respondents expressed concern about the potential for increased crime (Table 2.2-1). Similar decreases in concerns are indicated over increases in the cost of living, housing costs, school crowding and alcohol and drug abuse. Increases in negative outcomes were mainly associated with the completion of the project. On the anticipated benefits side (Table 2.2-2) many local expectations were not met, particularly with respect to employment. Both sets of results indicate the importance of local experience in developing a realistic understanding of the project effects and the value of expectations management by the proponent, government and others with the information available to do so.

The area around the Bull Arm site had experienced a number of large construction projects in the past, including the Long Harbour phosphorus reduction plant, the Come By Chance refinery and the Arnold's Cove fish plant. The Hibernia project, however, was the first to attempt to avoid or mitigate potential adverse negative socio-economic effects and create or enhance positive ones. The objectives of minimizing community disruption were achieved (see Table 3.3-4, Storey 1995; Storey et al. 1996), but of particular relevance to the White Rose Project is that the management process has evolved and the actual outcomes provide a basis against which the potential effects of subsequent projects can be assessed and understood.

Table 2.2–1 Anticipated Potential Negative Effects of the Hibernia Construction Project: Effects by Percentage of Respondents, 1985, 1992, 1996

Negative Effect	1985 (%)	1992 (%)	1996 (%)
Increased crime	51.2	51.4	2.6
Increased cost of living	33.8	16.2	2.6
Disruption of fishery	27.7	10.8	0.0
Increased housing costs	15.5	0.0	0.0
Overcrowded schools	9.2	0.0	0.0
Oil spills/pollution	6.2	2.7	5.2
People moving in	5.1	29.7	0.0
Alcohol/drug abuse	1.5	5.4	0.0
Low income people will suffer	0.0	5.4	0.0
Unemployment/adjustment to lower incomes	0.0	0.0	43.8
Out-migration	0.0	0.0	17.5
Business losses	0.0	0.0	7.0
Locals won't get jobs	0.0	0.0	4.4
Other	6.5	16.2	13.1

Source: Jones 1998.

Table 2.2–2 Anticipated Potential Benefits of the Hibernia Construction Project: Benefits by Percentage of Respondents, 1985, 1992, 1996

Benefit	1985 (%)	1992 (%)	1996 (%)
Employment in general	88.7	67.7	40.0
More municipal services	43.0	0.0	0.0
More people moving in	33.9	13.7	2.8
Employment for self/family	22.9	14.7	7.1
Economic benefits	3.8	16.7	0.0
Business opportunities	2.7	28.4	4.3
Community growth/development	1.8	8.8	0.0
Use site for future projects	0.0	0.0	32.9
Use facilities after project finishes (pool, etc.)	0.0	0.0	10.0
Training used for future employment	0.0	0.0	7.1
Other	3.2	6.9	1.4

Source: Jones 1998.

At the public consultation sessions for the Terra Nova, the Newfoundland Transshipment Terminal and White Rose projects such issues as the effects on housing, crime, demands on local services, etc., which many participants in the Hibernia consultations viewed as being potentially highly problematic, had largely disappeared as concerns. Instead, the primary issue discussed was how to secure maximum employment and business benefits. The focus of public attention has thus shifted in the light of experience, and the structure and focus of this document reflects that by identifying a smaller number of VECs and drawing attention to particular elements of concern within them. Accordingly, some of the concerns that it was felt necessary to address when the DA Guidelines (CNOPB 1988) were prepared are not given detailed attention here.

A case in point is the concern over the local "way of life." Prior to the Hibernia project, many were concerned that the introduction of an oil component to the provincial economy would have significant negative effects on Newfoundland society, its traditions and culture. While offshore activity has had a range of effects, including bringing some newcomers to the Province, increasing employment and incomes, and introducing new work patterns, there is no evidence that this has had significant detrimental effects. No concern was expressed in the public consultation sessions about the effects of the new industry on the traditional way of life.

Another issue which no longer appears to warrant the concern that it was given a decade or more ago is the ability of municipal governments to deal with offshore-related projects. The Hibernia project clearly demonstrated that they were. The Terra Nova project, which has been much smaller, has also had no effect and local governments appear to be well prepared to deal with future projects. No concerns were raised either prior to approval of Terra Nova or in connection with White Rose, which is a smaller project, regarding the capacity of municipal governments.

Similarly, the DA Guidelines call for assessment of socio-economic effects on municipal, electrical, other energy, transportation and telecommunications infrastructure and services, and on land and resource use and a variety of particular social services, such as those related to child care, alcohol and drug abuse, and services to the disabled. These are not subject to any detailed consideration here. These issues were not problematic during Hibernia construction, were not raised during the Terra Nova public consultation, and have not been a cause of concern during Terra Nova activity to date. Furthermore, such effects were also of little or no concern to key informants and members of the general public who participated in the White Rose issues scoping process.

The same is true for other issues for which the context has changed since the DA Guidelines were drafted. For example, when Hibernia was under review there was concern that movement of workers from the fisheries sectors to the offshore oil industry would have negative consequences for the former. This has not proven to be the case, rather offshore oil has provided opportunities for some fisheries workers since the restructuring of the fishery following the 1992 groundfish moratorium.

Similarly it was anticipated that “normal” population growth (i.e, without offshore oil) plus that from offshore development could result in significant demographic changes with consequent implications for a wide range of services and facilities. As is discussed in Chapter 3, the economic and demographic context of the 1980’s has changed significantly in the 1990’s and the experience of Hibernia and Terra Nova allows a re-evaluation of the demographic issues and characteristics that need to be addressed in the context of the White Rose Project.

Overall, the Terra Nova SEIS (Petro-Canada 1995) concluded that that project would have no significant social effects, and the Terra Nova Development Project Environmental Assessment Panel agreed: ‘The Panel is satisfied that the Proponents have supplied sufficient information for the Panel to determine that the development will not have significant negative social impacts’ (CEAA 1997). The 28 socio-economic recommendations of the Panel all relate to benefits and worker safety issues; none are concerned with effects on the social fabric of communities or the province as a whole.

What continues to be the major concern is the capture, by the Province as a whole and by particular regions, communities and social groups, of the economic benefits of offshore developments. Though excluded as an element of the SEIS by the DA Guidelines, the question is one that must be addressed directly. No socio-economic analysis in Newfoundland seems complete without consideration of employment and business effects and hence, they are generally discussed here. Further, specific information on employment and business considerations related to the project will be discussed in the Canada-Newfoundland Benefits Plan to be submitted to the C-NOPB as part of the DA.

2.2.2 Socio-Economic Effects Methods

The approach adopted comprises an examination of three main elements as follows:

Existing Environment - For each VEC, the specific geographic assessment boundaries are defined and the major characteristics of the existing environment described. The latter includes discussion of existing literature and data, and any characteristics or trends which might be expected to influence the nature of the VEC in the future without the Project.

Potential socio-economic environment-project effects for each VEC are first identified through a Project-Environmental Effects Interaction Matrix. Potential effects are considered in terms of project-related activities (construction, operation and decommissioning) and in terms of unplanned events (malfunctions, accidents, etc.) and cumulative effects (past, present and future projects). The nature of these effects is then described and analyzed. This includes the potential effects of the Project on the socio-economic environment, the effects of the socio-economic environment on the Project and any interactions between socio-economic and biophysical elements as they relate to the Project.

Cumulative Effects - The assessment of cumulative socio-economic effects, (that is, the relationship between the Project and other projects and activities that may affect the identified VECs) are treated in an integrated fashion as part of the overall socio-economic effects assessment (see Barnes and Davey 1999). The projects and activities considered are those that are ongoing or likely to proceed. They include the Hibernia and Terra Nova projects, offshore exploration commitments, and fishing and shipping activity in the vicinity of the Project.

Environmental Design and Effects Management - Where possible, technically and economically feasible measures are identified to avoid or minimize any negative Project effects and to create and enhance positive ones. Some effects management measures are already incorporated into the Project design and others will be integrated with the Canada-Newfoundland Benefits Plan to meet these objectives. Additional strategies are in response to other effects identified in the Project-environment interactions analysis.

Integrated Residual Environmental Effects – Project-related effects are described and summarized in two tables for each VEC. The first (see, for example, Table 4.4-1) considers whether the effects are positive or adverse and whether any mitigation is appropriate. This evaluation is undertaken for each project activity, unplanned events or cumulative effects elements described in the Project-Environmental Effects Interaction Matrix (see, for example, Table 4.3-1).

The basis for the evaluation are the following CEAA (1994) criteria:

- magnitude;
- geographic extent;
- duration and frequency;
- irreversibility; and
- socio-economic context.

Magnitude describes the nature and extent of the socio-economic effect for each activity. Geographic extent refers to the area affected by the Project (for example, the Province or the defined study area). Duration and frequency describe how long and, where relevant, how often a Project activity or socio-economic effect will occur. Reversibility refers to whether the VEC can, or likely will, return to an equal or improved condition at the end of the activity or Project life-cycle. The socio-economic context considers the current status of the area affected by the Project in terms of existing environmental conditions and effects. Each of these criteria is rated according to a set of defined values. The results of the analysis for each VEC and specific VEC components are summarized in tabular form.

Definitions for the rating criteria used differ between the fishery and other socio-economic VECs because of the type, location and group of individuals affected. For example, magnitude is defined in terms of current capacity to accommodate change in the case of social and physical infrastructure and services, while in the case of the fishery, magnitude reflects the proportion of fishers affected by Project-related changes. Thus in the former case, a magnitude of "1" implies a low magnitude effect, one that is within the capacity of the system in question, while "3" implies a high magnitude effect that exceeds current system capacity. In the case of the fishery, a magnitude of "1" is assigned where 0 to 5 percent of fishers are likely to be affected; "3" is assigned if more than 25 percent are predicted to be affected.

Similarly, geographic extent, duration, frequency, reversibility and socio-economic context are each defined in ways relevant to the community-related or fishery-related VECs. In all cases, the definitions adopted are included in a key to each table for each VEC.

From these results, any significant residual (that is, after management strategies are considered) effects, including cumulative residual effects, are identified. The magnitude of an effect is of particular importance in determining significance. An adverse effect assigned a magnitude of "2" or "3", after mitigation, is considered a significant adverse residual effect and more so where its geographic extent or temporal nature increases, where it is irreversible, or where it occurs in an area previously unaffected by human activity.

Each of these findings are then examined in terms of the level of confidence for the predictions and the likelihood of their occurrence, the latter based on the probability of the predicted outcome occurring, and scientific certainty. The results of the analysis are then summarized by assigning ratings of significance for each Project phase. This overall determination considers all residual socio-economic effects, including project and other-project cumulative effects, and provides an integrated residual socio-economic effects evaluation in tabular form for each VEC (see, for example, Table 4.4-2).

As part of the socio-economic effects analysis, appropriate monitoring and follow-up are described. The focus of these activities includes:

- where important or sensitive interactions are identified;
- situations where there is a high level of uncertainty about the socio-economic effects predictions;
- situations where significant adverse effects are predicted; and
- where commitments will be made as part of the Canada-Newfoundland Benefits Plan.

3 ECONOMIC AND DEMOGRAPHIC CONTEXT

3.1 INTRODUCTION

An understanding of the economic and demographic context within which the White Rose oilfield development will occur is fundamental to the analysis of its potential effects. This section summarizes the economic and demographic context in the province as a whole, as well as the St. John's, Isthmus and Marystown areas, the key study areas.

3.2 NEWFOUNDLAND AND LABRADOR

The 1990s were something of a "roller coaster" for the Newfoundland and Labrador economy and this is reflected in a number of provincial performance indicators (Table 3.2-1). The start of the decade saw the beginning of a new phase in the province's offshore oil industry with the commencement of construction of the Hibernia platform at Bull Arm. This $5.8 billion project, the largest construction project in North America at the time, created, at peak (in September 1995), some 6,100 jobs in Newfoundland (HMDC 1996a:3), and is reflected in the substantial increase in capital investment in the 1993 to 1996 period. Other oil-related activity during this period included the construction of the Newfoundland Transshipment Terminal and preparations for the development of the Terra Nova field (Department of Finance 2000a).

This positive development was dramatically offset in 1992, with the collapse of the northern cod stock and the declaration of moratoria on northern cod and a number of other groundfish species. In that year, approximately 32,000 Newfoundlanders and Labradorians were put out of work (Storey and Smith 1997) and between 1990 and 1994 the volume of fish landings fell by over 70 percent. These events have had a major effect on the economy and society.

Table 3.2–1 Selected Economic Indicators Newfoundland and Labrador 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999
Population as of July 1 (000's)	580.2	580.2	574.8	568.0	560.6	554.1	545.4	541.0
GDP at Market Prices ($Millions)[1]	9,550	9,767	10,257	10,649	10,429	10,231	10,871	11,638
Total Personal Income ($)	9,471	9,669	9,867	10,057	9,879	9,910	10,054	10,490
Per Capita Personal Income ($)	16,325	16,665	17,165	17,707	17,623	17,886	18,434	19,390
Labour Force, Annual Average (000's)	242.4	241.1	240.8	237.1	231.7	232.5	237.0	246.7
Employment, Annual Average (000's)	193.5	191.9	192.2	194.3	187.0	189.3	194.2	204.9
Unemployment Rate, Annual Average (%)	20.2	20.4	20.2	18.1	19.3	18.6	18.0	16.9
Wages and Salaries ($Millions)	4,570	4,624	4,769	4,854	4,696	4,663	4,779	4,964
Consumer Price Index (1992=100)	100.0	101.7	102.9	104.4	106.0	108.2	108.4	110.0
Total Volume of Fish Landings (000's Metric Tonnes)	278.0	241.6	127.5	131.6	181.5	206.0	249.5	265.6
Total Value of Fish Landings ($Millions)	179.3	194.4	201.4	329.8	263.8	308.8	381.4	518.0
Newsprint Shipments (Thousands of Metric Tonnes)	666.6	703.9	736.6	734.7	713.7	740.9	569.8	722.2
Value of Mineral Shipments ($Millions)	705.9	698.9	838.3	881.5	911.3	1,010.1	1,095.8	832.8
Iron Ore Shipments (Millions of Metric Tonnes)	17.7	18.2	20.3	20.0	19.7	21.7	21.6	19.1
Gross Value of Manufacturing Shipments ($Millions)	1,279.6	1,322.6	1,422.9	1,639.0	1,618.3	1,659.7	1,750.1	1,979.6
Mfg. Fish Product Shipments ($Millions)	413.3	414.3	393.8	416.0	438.6	462.5	562.2	656.6
Private and Public Capital Investment ($Millions)	2,110	2,467	2,942	2,937	2,405	2,738	2,774	3,358
Dwelling Starts (Number)	2,271	2,405	2,243	1,712	2,034	1,696	1,450	1,371
Retail Trade ($Millions)	3,364	3,340	3,430	3,510	3,543	3,772	3,884	4,150
New Motor Vehicle Sales (Number)	19,410	19,544	20,225	17,112	16,199	20,985	21,472	24,421

[1] 1997-1999 GDP and 1999 Personal Income estimates provided by Economic Research and Analysis Division, Newfoundland Department of Finance

Note: Some data are preliminary

Source: Statistics Canada, Economics and Statistics Branch, Department of Finance

A major consequence of the closure of the fishery has been the decline of the population since 1991-92 (Table 3.2-2). There was a net loss of nearly 18,900 people between 1991 and 1996 and a further loss of 19,600 between 1996 and 1999. As might be expected, these losses have particularly affected rural Newfoundland. This blow to the economy was reflected in higher unemployment rates (20.4 percent in 1994) (Table 3.2-1), a decline in the labour force, decreases in retail trade, and declining housing starts.

Table 3.2–2 Population of Newfoundland and Labrador, 1981-1999

Year	Population	Change (%)
1981	574,800	--
1986	576,500	3.0
1991	579,500	5.2
1996	560,600	-3.3
1999[1]	541,000	-3.5

[1] Preliminary estimate
Source: Statistics Canada 2000b

At the same time, however, the closure of the fishery was partially offset by performances in other sectors. The value of mineral, newsprint and manufacturing shipments were all increasing through 1994 (Table 3.2-1), by nearly 20 percent over 1993 in the case of mineral shipments.

By 1995, there were indications that the economy was starting to rebound. The resource industries were producing a strong showing, and upward movement in world commodity prices had boosted the value of newsprint, mineral products and shellfish. The Hibernia project continued to be a major contributor to growth and the discovery of the Voisey's Bay deposit generated unprecedented interest in the mineral potential of Labrador, resulting in the highest level of mineral exploration in many years. West Coast oil exploration also intensified. The overall effect was increased employment, wages and retail trade, and decreased unemployment.

Despite some weaknesses resulting from changes in unemployment insurance benefits, and budget reductions that affected public sector spending, the longer-term prospects for the economy, especially in the resource sector, looked favourable.

Unfortunately, this did not prove to be the case in 1996 and 1997. 1n 1996, the GDP declined and personal incomes were down from the previous year. Contributing factors included the beginning of the wind-down of the Hibernia construction project and declining values of newsprint shipments and fish landings. By 1997, the situation was worse, the exceptions being the recovery of the fishery (driven mainly by crab and shrimp landings which has continued until the present) and the production of first oil from Hibernia. The year saw further declines in GDP, personal income, and the total population. (Table 3.2-1)

Throughout the 1990s, net migration losses had been increasing, but with limited prospects for the return of the cod fishery, changes in the structure of the fishery, and the winding down of The Atlantic Groundfish Strategy (TAGS), out-migration increased. In 1990-91, annual net loss had been 711 residents, the lowest for more than 20 years, but by 1997-98, it had reached 9,490, by far the highest annual loss in the same period (Table 3.2-3).

Table 3.2–3 Interprovincial Migration, Newfoundland and Labrador, 1981-1999

Census Year[1]	In	Out	Net
1981-82	9,393	13,915	-4,522
1982-83	9,705	8,419	1,286
1983-84	6,271	8,763	-2492
1984-85	5,982	9,679	-3,697
1985-86	6,045	11,742	-5,697
1986-87	7,951	12,611	-4,660
1987-88	9,259	12,639	-3,380
1988-89	10,105	11,895	-1,790
1989-90	10,705	12,726	-2,021
1990-91	10,346	11,057	-711
1991-92	9,266	10,935	-1,669
1992-93	7,558	10,636	-3,078
1993-94	6,580	11,532	-4,952
1994-95	6,406	13,380	-6,974
1995-96	7,005	14,441	-7,436
1996-97	6,962	15,096	-8,134
1997-98	7,392	16,882	-9,490
1998-99	10,988	16,613	-5,625

[1] July 1 to June 30

Source: Statistics Canada 2000a.

Note: Figures do not include International Migration

Economic performance in 1998 and 1999 perhaps best exemplifies the "roller-coaster" designation for the decade. Two years of comparatively poor performance were followed by two of exceptionally strong economic growth. In 1998 and 1999, GDP increased by 6.6 and 7.1 percent, respectively. Personal incomes increased by 1.5 and 4.3 percent, respectively and retail trade was up by 3.0 and 6.9 percent, respectively. Capital investment increased by 21 percent in 1999, led by expenditures on Terra Nova, the expansion of the Newfoundland Transshipment Terminal, the St. John's Civic Centre, the Davis Inlet relocation, and municipal infrastructure.

In 1999, real GDP growth was 5.3 percent and Newfoundland and Labrador posted the strongest economic growth of any province for the second year running. Exports (13.1 percent) and capital investment (21 percent) both reached record levels. The economic gains were broadly-based and included increases in offshore oil production, crab and shrimp landings, construction, tourism and manufacturing (Department of Finance 2000a). Strong economic growth, coupled with employment growth of 5.5 percent, higher wages, low interest rates and strengthened consumer confidence, helped retail sales and contributed to a significant increase in in-migration

(Table 3.2-3). As is discussed in Chapters 1 and 4, Hibernia, Terra Nova and White Rose have made a particularly significant contribution to this growth (Department of Finance 2000a).

Net increases from births over deaths (Table 3.2-4) are currently small, but reductions in net migration losses in particular (Table 3.2-3) helped to stabilize the population in the third-quarter of 1999, leaving population virtually unchanged from the previous quarter.

Table 3.2–4 Natural Increase Components of Growth, Newfoundland and Labrador, 1981-1999

Census Period	Average Births per Year	Average Deaths per Year	Average Net Increase per Year
1981 - 1986	8,826	3,478	5,348
1986 - 1991	7,660	3,702	3,958
1991 - 1996	6,405	3,905	2,500
1996 – 1999[1]	5,310	4,327	983

[1] Preliminary estimate

Source: Statistics Canada 2000b

While expectations may have been dampened by recent announcements of reductions in crab and some groundfish quotas, the forecasts for 2000 (Department of Finance 2000a) see a continued growth in GDP (4.7 percent), led by increased oil production and stronger markets for some commodities. Employment is expected to grow by 2.8 percent and the unemployment rate to decline to 15.9 percent, the lowest in the past decade. Strong growth in tourism associated with the Viking Millennium celebrations, the manufacturing sector (sales expected to exceed $2 billion), increased oil and gas production and continued investment in new offshore projects, are expected to lead this growth.

The population is expected to stabilize in 2000 and beyond, as net out-migration continues to moderate. While population decline is not expected to be an issue in the current decade, population ageing and regional population shifts will continue to present challenges for the province (Department of Finance 2000a).

3.3 ST. JOHN'S AREA

The St. John's area economy has fared comparatively well by provincial standards over the past decade, and is currently enjoying a boom in economic growth and activity. Intercensal demographic changes in the St. John's area and the City of St. John's since 1981 are illustrated in Table 3.3-1. The area as a whole has been growing, although at a rate that has been in decline. The total population grew by only 1.3 percent in the 1991 to 1996 period, with most of this occurring in Mount Pearl and Conception Bay South.

Table 3.3–1 Population and Intercensal Changes, St. John's Area and City, 1981-1996

Year	St. John's Area		City of St. John's	
	Population	Intercensal Change (%)	Population	Intercensal Change (%)
1981	154,820	6.5	83,770	-3.3
	154,835[1]		96,455	
1986	161,901	4.6	96,216	-0.2
1991	171,859	6.2	95,770	-0.5
			104,659[2]	
1996	174,051	1.3	101,936	-2.6

[1] 1986 boundaries

[2] 1996 boundaries

Source: Statistics Canada 1981; 1986; 1991; 1996.

By contrast, the population of the City of St. John's has been declining. Boundary changes have periodically increased the area and the total population but, based on analysis of comparable areas, the population has decreased. From 1991 to 1996, the decrease was 2.6 percent. The City of Mount Pearl, by contrast, has had a growing population. From 1981 to 1991, it grew by 35.5 percent to 23,676, and from 1991 to 1996 by 7.8 percent to 25,519 (Statistics Canada 1981; 1991; 1996).

The City of St. John's, though it has lost population, and the City of Mount Pearl in particular, have experienced substantial economic growth recently. St. John's is currently experiencing a wave of construction activity, including the new Janeway Hospital, the civic centre and convention facility, and The Rooms, the new provincial art gallery and archives complex. In addition, the Outer Ring Road will be completed by 2003, the St. John's Airport is undergoing a $48 million redevelopment, there has been expansion and redevelopment at the St. John's Dockyard (NEWDOCK), and the St. John's Port Authority is engaged in a $13 million upgrade of Pier 17. Mount Pearl, home to the Donovan's Industrial Park, the province's largest, has experienced economic growth across a number of sectors, but offshore-related development has been particularly important. These and other infrastructure developments are discussed further in Chapters 4 and 6 of this report.

Developments in other areas, particularly the technology sector, are also contributing to local economic growth. For example, the Canadian Centre for Marine Communications recently signed a $2.5 million Marine Information Skyway initiative with the Canadian Space Agency to develop commercial satellite technology applications for the marine environment. This, and other developments that require good market access, are facilitated by the area's telecommunication infrastructure. This includes what is described as one of the deepest penetrations of fibre-optic and digital technology in Canada: high-speed hybrid-fibre-optic-coax network; high-speed Asymetric Digital Subscriber Line (ADSL); and CANARIE National Network with speed of 45 megabits per second for research, development and testing of broadband network applications (Atlantic Progress 2000). Growth in this and other sectors has been aided by the cost-effectiveness of doing business in the region. Studies by KPMG in 1998 and 1999 showed that location-sensitive business costs such as labour, electricity, taxes and transportation, were significantly lower in St. John's compared with other cities evaluated (KPMG 1999).

3.4 ISTHMUS OF AVALON AREA

The Isthmus of Avalon area has not fared as well as the St. John's area, but its relatively diverse economy and the benefits of the Hibernia project have sheltered it from much of the economic disruption experienced elsewhere in the Province. Population changes between 1981 and 1996 (the most recent data available) for the Isthmus of Avalon area are illustrated in Table 3.4-1. Overall, the population has changed very little since 1981, but within the area, Clarenville-Shoal Harbour shows a consistent growth pattern (29 percent between 1981 and 1996), while all other areas, with the exception of Random Island, have shown overall decreases.

In 1991, the area had a labour force of 7,460, of which 26.5 percent were unemployed. By 1996, the labour force had increased to 7,875 but the percentage unemployed had declined to 23.5 percent (Statistics Canada 1991; 1996). During the past decade, the Isthmus area has been involved with the construction at the Bull Arm facility and of the Newfoundland Transshipment Terminal at Whiffen Head. The Newfoundland Transshipment Terminal, built to handle oil production from Hibernia, Terra Nova and future oilfields, has already undergone expansion since it was first constructed.

Other sectoral activities that have contributed considerably to the local economy include North Atlantic Petroleum's Come By Chance refinery and the associated new sulphur drilling plant, the National Sea Products fish plant at Arnold's Cove and the Clarenville crab processing plant. Employment at these and other businesses in the area, combined with out-migration, have helped reduce the number of people needing social assistance support in recent years (see Section 5.4).

Table 3.4–1 Population, Isthmus of Avalon Area, 1981-1996

Consolidated Census Sub-Division	Population			
	1981	1986	1991	1996
CCSD 1A: Isthmus				
Arnold's Cove	1,124	1,117	1,106	1,115
Chance Cove	498	467	435	394
Chapel Arm	689	699	638	575
Come By Chance	337	266	296	300
Long Harbour/Mt. Arlington Heights	660	627	522	472
Norman's Cove/ Long Cove	1,152	1,107	1,054	988
Southern Harbour	772	742	716	635
Sunnyside	703	634	622	621
Unincorporated	1,162	1,128	1,114	1,039
Total	7,097	6,787	6,503	6,139
CCSD 2K: Swift Current				
Unincorporated	888	869	839	752
Total	888	869	839	752
CCSD 7K: Smith Sound				
Clarenville-Shoal Harbour	3,878	4,016	4,473	5,335
Unincorporated	1,240	1,306	1,357	1,279
Total	5,118	5,322	5,830	6,614
CCSD 7L: Random Island				
Unincorporated	1,564	1,646	1,685	1,627
Total	1,564	1,646	1,685	1,627
CCSD 7M: South West Arm				
Unincorporated	3,033	3,054	2,988	2,808
Total	3,033	3,054	2,988	2,808
Total Study Area	17,700	17,678	17,845	17,940
Percent Change		-.12	.94	.53

Source: Statistics Canada 1981; 1986; 1991; 1996.

3.5 MARYSTOWN AREA

The population of the Marystown area declined in the 1991 to 1996 period by 3 percent (Table 3.5-1). Marystown itself has remained stable, while the largest losses have been in Burin (8.8 percent). Of the other communities in the area, only Winterland saw growth.

Table 3.5–1 Population, Marystown Area, 1981-1996

Consolidated Census Sub-Division	Population			
	1981	1986	1991	1996
CCSD 2D: Marystown				
Fox Cove-Mortier Bay	465	500	464	442
Marystown	6,305	6,660	6,739	6,742
Winterland	235	260	272	318
Unincorporated	400	375	349	322
Total	7,405	7,795	7,824	7,824
CCSD 2E: Burin				
Burin	2,900	2,890	2,940	2,682
Lewin's Cove	510	555	609	604
Port au Bras	365	360	319	268
Unincorporated	335	310	302	263
Total	4,110	4,115	4,170	3,817
CCSD 5H: Garnish[1]				
Frenchman's Cove	295	275	229	220
Garnish	760	755	716	691
Total	1,055	1,030	945	911
Total Study Area	12,570	12,940	12,939	12,552
percent change	6.6	2.9	0.0	-3.0

Source: Statistics Canada 1981; 1986; 1991; 1996.

The economic fortunes of the area primarily reflect what has been happening in the fishery and activity at the Marystown shipyard. The effects of the fisheries moratoria can be inferred from the population changes in Burin in particular, but the closures have affected the entire area. Activities at the shipyard are discussed in more detail in Chapter 4. Suffice to say that Hibernia-related work was of particular importance to the yard between 1993 and 1995, as was subsequent work constructing the tugs for the Newfoundland Transshipment Terminal. The Terra Nova project and Husky Oil have also provided more recent work for the shipyard.

4 BUSINESS AND EMPLOYMENT

4.1 INTRODUCTION

Recognizing their importance in the Newfoundland context, and further to the *Atlantic Accord Implementation Acts*, the C-NOPB DA Guidelines (C-NOPB 1988) require that the economic effects of a development project be discussed in a separate document, the Canada-Newfoundland Benefits Plan. Accordingly, the DA Guidelines explicitly exclude these effects from the analytical scope of the SEIS. Similarly, CEAA does not require assessment of economic effects unless they result from biophysical effects or unless the TOR for the project are written to specifically include them if they are not addressed elsewhere.

However, as discussed in Chapter 2 and clearly demonstrated by comments from participants in the White Rose public consultation process, business and employment issues are of fundamental concern. As outlined in Chapter 2, employment and business activities are valued by individuals who may benefit directly or indirectly from such things as:

- work in its own right;
- changes in incomes and standards of living; and
- development of skills and expertise.

A new project such as White Rose will be beneficial insofar as more people will be employed and successive rounds of employee and business expenditures will generate employment and income multiplier effects in the local and provincial economies. The employment and business effects of the Project will be influenced by Husky Oil's Canada-Newfoundland Benefits principles and practices. Issues and commitments respecting business and employment will be fully discussed in the Canada-Newfoundland Benefits Plan which will be submitted and thoroughly reviewed as part of the C-NOBP DA process. However, to emphasize the importance of employment and business issues in particular, this section does provide an overview assessment of the effects of the project on the business and employment VEC.

The assessment approach comprises the three main components described in Chapter 2, namely a discussion of the:

- existing socio-economic environment, including
  - the particular environmental assessment boundaries relevant to employment and business, and
  - existing conditions with respect to each of these components;
- socio-economic effects assessment, including
  - an overview of project-environment interactions,

- a discussion of socio-economic effects, including cumulative effects, and
- a summary of socio-economic management initiatives to address potential effects;

- integrated residual socio-economic effects, including
  - a summary of residual socio-economic effects significance by project phase, and
  - a discussion of monitoring and follow-up initiatives.

4.2 EXISTING SOCIO-ECONOMIC ENVIRONMENT

4.2.1 Assessment Boundaries

The boundaries described in Chapter 2 provide the basis for the assessment of business and employment. In the case of the St. John’s, Isthmus of Avalon and Marystown areas, the focus is on communities within an easy commute range of the main possible project-related workplaces. While some workers may travel considerably greater distances, this primary commuting zone is assumed to have an approximate 50-km radius. It is further assumed that indirect and induced business opportunities will also be concentrated within these zones. As a result, the assessment uses baseline data related to census subdivision units that approximate this zone, or in the case of the St. John’s area, the CMA.

While the Province is divided into a number of economic divisions, including the regional economic development board zones, none of these approximate or influence the distribution of business and employment in ways that would make an alternative choice of boundaries more appropriate.

4.2.2 Existing Conditions

4.2.2.1 Newfoundland

As was discussed in Chapter 3, 1999 saw Newfoundland post the strongest economic growth of any province for the second year running. The real GDP growth of 5.3 percent was led by gains in exports and capital investment, both of which reached record levels. Economic gains were broadly based, and included increases in offshore oil activity, crab and shrimp landings, construction activity, tourism and manufacturing. As discussed in Section 1.2 the oil industry was the leading contributor to this growth in the provincial economy. In addition, manufacturing gains, led by fish production, newsprint and refined petroleum, resulted in a record shipment value of almost $2 billion. Strong economic growth, coupled with increasing employment, higher wages, low interest rates, and strengthened consumer confidence, led to a 6.9 percent increase in retail sales (Department of Finance 2000a).

This economic growth was reflected in the labour market, with 1999 seeing the best performance in a decade. Employment averaged 204,900, up 5.5 percent from 1998. This was the highest growth of any province, and double that of Canada as a whole. The 1999 unemployment rate was 16.9 percent, down from 18.0 percent in 1998. There were job gains in the fisheries, retail trade, construction, tourism and transportation industries, with employment growth outside of the St. John's area being particularly strong, at 8.1 percent (Department of Finance 2000a).

4.2.2.2 St. John's Area

The St. John's area has shared the recent economic success enjoyed by the Province. In 1991, the unemployment rate for the CMA was 16.1 percent; this had fallen to 14.2 percent by 1996 (Statistics Canada 1991; 1996). This trend continued in the following years and by 1999, the CMA unemployment rate had fallen to 10.0 percent by March 2000. At the same time, there has been a small increase in the labour force, from 89,660 in 1991 to approximately 93,800 in 1999 (Statistics Canada 2000c). These steep declines in the unemployment rate reflect, in part, the important contribution the offshore oil industry is already making to the St. John's area economy.

Since the earliest days, St. John's has been the main location for administrative, engineering, regulatory, training, supply base, air transportation and service activities. There has also been some fabrication work in St. John's. These activities are reflected in oil industry-related capital expenditures in the region. For example, spending on the Cougar helicopter terminal, the A. Harvey and Company offshore supply base, the Hibernia Integrated Well Services shops and warehouse, the Hibernia training simulator, pipeyard and warehouse, the Halliburton Operations Centre, the NEWDOCK sub-sea systems fabrication centre, and the Pennecon supply base in Bay Bulls, has totalled over $34 million since 1996.

In addition, the growth of the oil industry has been accompanied by the development in St. John's of an impressive array of education, training, and research and development facilities. This has involved construction at: Memorial University of Newfoundland (including the Centre for Earth Resources Research and Centre for Cold Ocean Resources Engineering) worth approximately $46 million; the Fisheries and Marine Institute (including the Marine Offshore Simulator Training Centre, and the Offshore Safety and Survival Centre in Foxtrap) worth $22 million; and the College of the North Atlantic (CNA) (including Petroleum Technology Training Program equipment) worth $25 million (Department of Industry, Trade and Technology 1998).

Ongoing oil industry activities have brought a range of economic benefits to the St. John's region. For example, a study of Hibernia operations in 1998 indicated that most of its employees live in the St. John's area, with considerable spin-off effects on the education, housing, retail, entertainment, arts and other sectors. Furthermore, in that year, the Hibernia Management and Development Company (HMDC) and 14 of its partners or major contractors used approximately 160,000 square feet (14,865 m^2) office, commercial and industrial space in the City of St. John's. These properties contributed to the local economy through their direct and indirect employment and business effects, including the rents paid and the requirements for janitorial, maintenance, office supplies and other such services. This space had a total assessed value of approximately $13.2 million, generating over $250,000 per annum in municipal tax (HMDC 1999).

Similarly, between the beginning of 1996 and mid-May 1999, 52 new oil and gas-related businesses were set up in Mount Pearl. This included operations largely or entirely dedicated to work on the Hibernia and Terra Nova projects. The City of Mount Pearl estimates that, in total, these businesses employed 471 people and represented almost $10 million in property values. As such, they generated almost $300,000 in annual municipal tax revenues, representing over 2 percent of all revenues (HMDC 1999).

Husky Oil has been making its own contribution to the economy of the St. John's region. The 1999 employment and expenditures described above were primarily concentrated in the City of St. John's, where its regional office, supply base, air transportation and other facilities are located, and where much of its project development, education and training, and research and development work has occurred. The regional office, which opened in 1997, has been responsible for managing all operational aspects of its programs on the Grand Banks. The project management personnel based in this office have decision-making authority for all operational aspects, including procurement.

4.2.2.3 Isthmus of Avalon Area

The Isthmus of Avalon has had fluctuating economic fortunes over the years, in response to changing circumstances in the provincial economy, in the fishery, and with major industrial projects within and close by the region, such as the Come by Chance refinery, the Long Harbour Phosphorus Reduction facility, the Argentia Naval Base, and the Bull Arm construction yard. In 1991, the Isthmus area had a population of 17,845 and a labour force of 7,460, of whom 1,980 (26.5 percent) were unemployed. By 1996, there had been a slight increase in the population to 17,940, and an increase in the labour force to 7,875, but unemployment was down to 23.5 percent (Statistics Canada 1991; 1996).

The Isthmus area has had a number of important involvements with the offshore oil industry over the last decade. It is the site of both the $470 million Bull Arm construction and fabrication facility and the $150 million Newfoundland Transshipment Terminal. The first of these, located on Trinity Bay approximately 3 km south of Sunnyside, saw most of the Newfoundland-based construction and fabrication activity on the Hibernia production platform, and employed at peak about 5,800 workers. Over the life of the project, an average of about 7 percent of this labour force were from the local area (defined as communities within 50 km of the site).

As of June 1995, the project had also awarded local area businesses contracts worth over $34 million (HMDC 1996a).

The Newfoundland Transshipment Terminal is located on Placentia Bay, close to Arnold's Cove. The first two phases, which provide sufficient capacity to handle Hibernia and Terra Nova production, cost approximately $300 million (excluding the construction of two tugs in Marystown). The terminal itself currently employs 21 people, while a further 18 people work on the tugs. Local area expenditures exceed $100,000 a year (H. Mott, pers. comm.).

4.2.2.4 Marystown Area

The Marystown area has also had fluctuating economic fortunes over the years. It has been highly dependent on fishing (including the trawler fishery), fish processing and the shipyard. In 1991, it had a population of 12,939 and a labour force of 5,995, of whom 1,370 (22.8 percent) were unemployed. By 1996, the population had fallen to 12,552, and the labour force to 5,465. The number of unemployed, however, had increased to 1,850, resulting in an unemployment rate of 33.8 percent (Statistics Canada, 1991; 1996).

The shipyard is the largest shipbuilding and repair facility in the Province, and it has led to Marystown being involved in the Newfoundland oil industry since its early years. The shipyard has long been the site of rig commissioning, decommissioning and maintenance activity. This led to the $40 million investment in the Cow Head Fabrication Facility in the early 1990s.

Marystown shipyard, including the Cow Head facility, performed approximately $120 million worth of work on the Hibernia project between June 1993 and the end of 1995; this represented 80 to 85 percent of the company's throughput over the period. Specific projects included work on mooring pontoons, access systems and two supply vessels (HMDC 1995). The shipyard also constructed the specialized tugs used by the Newfoundland Transshipment Terminal and has undertaken small fabrication tasks related to the Terra Nova development project.

The Marystown area has also derived benefits from Husky Oil's exploration activity. In the Spring of 2000, the Sedco 714 semi-submersible drilling rig was subject to work at the shipyard. This saw, primarily, winterization, lifeboat enhancement and maintenance activity, generating about 35,000 to 40,000 person-hours of work. It resulted in the purchase of significant goods and services locally, in Newfoundland, and elsewhere in Canada.

4.3 SOCIO-ECONOMIC EFFECTS ASSESSMENT

4.3.1 Project-Environment Interactions

The types of Project-business and employment environment interactions that could be expected from the White Rose oilfield development are indicated in Table 4.3-1. White Rose will have a range of economic effects on Newfoundland and Canada throughout the construction/installation and operations phases in particular, but also in terms of its cumulative effects in conjunction with other offshore and industrial projects. These effects will be felt in the Province as a whole, but will be concentrated in those areas containing companies that secure construction contracts, and the St. John's area, which will be the base for operations.

Table 4.3–1 Project-Environmental Effects Interaction Matrix Business and Employment

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting	X		X	X	X	X	X	X
Subsea Units Fabrication	X		X	X	X	X	X	X
Field Development/Installation	X		X	X	X	X		
Operations								
Administration			X	X				
Supply Base/Warehousing			X	X				
Helicopter Transport			X	X				
Offshore Production/Marine Support	X		X	X				
Tanker Transport	X		X	X	X	X		
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events	X		X	X				
Past/Present/Future Projects								
Construction	X		X	X	X		X	
Operations			X	X				

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

4.3.2 Socio-Economic Effects

4.3.2.1 Newfoundland

The White Rose oilfield development will have a range of positive economic effects throughout all phases. The positive effects anticipated reflect, in part, Husky Oil's commitment to Canada-Newfoundland benefits. Husky Oil strongly supports providing opportunities to Canada and in particular, Newfoundland, and wishes to bring the maximum benefit to the region where practically and commercially achievable on a competitive basis. Husky Oil also believes that it makes economic sense to perform as much work as possible close to the field location.

The *Atlantic Accord Implementation Acts* provide the legislative framework for the development of Newfoundland's offshore resources, and require that development activity benefit Canada as a whole and, in particular, the Province of Newfoundland and Labrador. Husky Oil believes that by taking a proactive approach and in a competitive context, significant work and employment can be provided to residents of Newfoundland and elsewhere in Canada in a cost-effective and efficient manner.

Husky Oil's Canada-Newfoundland opportunities philosophy is based on its beliefs and guiding principles. Husky Oil beliefs applicable to Canada-Newfoundland opportunities are summarized as follows:

- Substantial skill base
  - there is a substantial skill base in Newfoundland and Labrador and other parts of Canada,
  - the availability of the skills base is largely dependent on its international competitiveness and timing of projects,
  - the combined resources of the engineering community and labour force in Newfoundland and Labrador and the rest of Canada can provide a significant portion of the skills required to carry out the work required.

- Substantial industrial base
  - the capabilities and resources exist to perform much of the required work in Newfoundland or elsewhere in Canada.
  - the opportunty for the industrial base is largely dependent or its international competitiveness and timing of projects.

- Training and transfer of technology
  - training and transfer of technology to local Canadian companies reduces long-term operating costs and provides effective programs and project support,
  - early training and transfer to Newfoundland and Canadian companies and individuals will increase long-term returns for all stakeholders,
  - Husky Oil recognizing the importance of determining training and upgrading requirements early in the project development to allow public and private sector responses to opportunities.

- Rights of government and people
  - Husky Oil recognizes the right of Newfoundland and Labrador to be one of the principal beneficiaries of the oil and gas resources off its shores, consistent with a requirement of a strong and united Canada.

- Husky Oil understanding
  - Husky Oil understands the objectives, conditions and commitments necessary to achieve cost-effective Canadian and Newfoundland and Labrador content.

Husky Oil has documented the principles that will guide its approach to the identification and provision of opportunities for Canada-Newfoundland participation. These principles are summarized as follows:

- Full and fair opportunity – goods and services
  - within a competitive framework, Husky Oil will provide full and fair opportunity for Canadian, and in particular, Newfoundland and Labrador companies to participate in the supply of goods and services by:
  - sizing and design of packages to fit the capabilities of Canadian and in particular, Newfoundland and Labrador companies;
  - development and use of vendor databases;
  - investigation of labour and fabrication capabilities;
  - early dissemination of information on the scope of work;
  - open communication with all personnel and companies requesting non-proprietary information;
  - presence of engineering, procurement and project management in Newfoundland and Labrador;
  - open communication with government and industry associations to identify potential suppliers; and
  - assisting and advising on the development and implementation of transfer of technology and training programs for long-term cost effectiveness.

- First consideration to Newfoundland and Labrador and Canada
  - Husky Oil supports the principle that first consideration be given Newfoundland and Labrador for labour, goods, services, etc., where they are competitive in terms of fair market price, quality and delivery,
  - Husky Oil will require that residents of Newfoundland and Labrador and other Canadians will be given early and ample opportunities for employment and related training.

- Proactive
  - Husky Oil is proactive in its approach to Canada-Newfoundland opportunities.

- "Value adding" is an imperative
  - Husky Oil, in evaluating of opportunities, will emphasise "best value" for the project.

As noted above, a full description of Husky Oil's benefits policies, procedures and commitments will be provided in the Canada-Newfoundland Benefits Plan. These policies, procedures and commitments will ensure that:

- a broad range of business, employment and industrial benefits result from the Project during both the development and operations phases; and
- disadvantaged individuals and groups have access to employment opportunities and related training.

Comparisons with the Terra Nova project offer some indication of the potential benefits. As noted in Section 1.2, its average monthly direct employment in Newfoundland increased from 210 in 1998 to approximately 950 in 1999 and projected peak of 1,300 in 2000, while total spending in 1999 was approximately $800 million (Department of Finance 2000a). During the operations phase for Terra Nova, direct employment is expected to require a permanent workforce of approximately 400 persons onshore and offshore during peak drilling years (Petro-Canada 1995). Indirect and induced employment effects will add to this.

The potential for Canadian and Newfoundland involvement in Project construction and operations activity on a competitive basis is potentially constrained by industrial and labour capability and capacity. If suitable infrastructure and other industrial capacity are not available, whether because they do not exist, are otherwise engaged or cannot be developed in time, the work will necessarily take place outside Newfoundland and/or Canada. Similarly, if suitable workers do not exist, are otherwise engaged, and/or cannot be trained in time, the work will go to non-Newfoundland and non-Canadian workers.

The business and employment effects of the Project will therefore depend not only on the existing business capabilities and labour force and how they might be increased or enhanced, but also other, cumulative, demands on them. Thus, for example, other major construction projects may draw on the same industrial capacity and workers as will White Rose development activity.

In Newfoundland, the main such projects are the Terra Nova project, the Voisey's Bay mine/mill, the Voisey's Bay processing facility, the Churchill Power project and, perhaps, the Hebron-Ben Nevis development. The potential interactions between each of these and White Rose are determined by the project characteristics including, critically, their timing. These characteristics are, in most cases, highly uncertain. However, consultation with government and industry sources suggests the following:

- Terra Nova: As is discussed elsewhere, the White Rose and Terra Nova offshore projects will use a large range of identical or similar industrial and labour capacity. However, given current Terra Nova project timing, there should be little or no overlap in these demands, because Terra Nova activity will be ending prior to the start of White Rose activity. Indeed, one of the great merits of the White Rose project, as currently proposed, is that it may provide some continuity in the use of these resources, minimizing booms and lulls in activity.

- Voisey's Bay: The $1.7 billion Voisey's Bay mine/mill, on the North Labrador Coast, and the associated $1.5 billion processing facility, proposed for Argentia on the west side of the Avalon Peninsula, are currently on hold. Were they to proceed, they would require some specialist mining and minerals processing capabilities; however, they would also draw on some construction facilities and labour that might be used for the Project. For example, the mill could be made up of modules that could be built in Bull Arm. However, it currently appears very unlikely that work on the Voisey's Bay projects will start before 2003 and hence, no demand conflicts are anticipated.

- Churchill Power: This $6-7 billion project will see the construction of dams and dykes to divert the Romaine River, the Gull Island Dam, powerhouse and switchyard on the Hamilton River, and associated power-lines. There is ongoing consideration of a dam at Muskrat Falls, but the economics are not yet proven, and a transmission line to the island is uncertain due to financing problems. It would employ, at peak (likely the third year of construction), 2,500 to 5,000 workers. A large part of the work will involve dam construction, which employs concrete construction equipment and skills quite different from those construction resources required by the Project. Furthermore, while other work might draw on common industrial and labour capacity to that required for White Rose, it currently appears very unlikely that work on the Churchill River Power Project will start before 2004 and hence, no demand conflicts are anticipated (L. Grattan, pers. comm.).

- Hebron: The proponents of this offshore oilfield development project are in the early stages of resource assessment and have yet to indicate that they wish to proceed. Hence, it seems likely that there would only be resource conflicts with the latter stages of the Project. Such overlap is likely to be minor, and it may, if the proponents decide to proceed, provide continuity of demand for facilities and labour.

There are few projects in the Maritimes that might have any cumulative effects. The most recent Atlantic Provinces Economic Council Major Projects Inventory (APEC 1999) identifies only three projects that are greater than low probability projects, have a capital value of $500 million or more, and are expected to extend into the White Rose construction period:

- Scotian Shelf Development: Further development on the shelf to 2007 is seen as being worth approximately $750 million. Such development is regarded as being of high probability.

- Natural Gas Distribution: This $600 million to $1,100 million project in Nova Scotia is seen as being of medium to high probability for the period to 2004. It would generate between 1,500 and 2,300 construction jobs.

- Strait Area Petro-Chemical Plant: This medium to low probability $600 million project would see the construction of an ethylene/polyethylene plant, with work completed by 2002. It would require 1,500 construction workers.

This analysis suggests that, given the current Project schedule, there will be only limited conflicts between industrial and labour requirements of White Rose and those of other major projects. However, this would change were there to be any long-term delay in the start of White Rose work. This would certainly result in a lull in resource demands between current project and White Rose construction, which might lead to some loss of capacity (as, for example, Newfoundland fabrication workers move to other projects in Newfoundland or elsewhere in Canada). It may result in construction work on the Project occurring coincident with that on one or more of these other major projects. This would produce a 'boom' in activity that might well exceed local capacity, resulting in a loss of industrial and employment benefits to Newfoundland and, perhaps, Canada.

There will similarly be other demands on infrastructure and labour required for operations. Hibernia, Terra Nova and White Rose, together with any subsequent fields, will need similar shorebase facilities and related industrial and labour support. This is not viewed as problematic, given that such demand provides long-term opportunities, justifying investments in infrastructure and training. This conclusion was supported by the White Rose public consultations, where neither key informants nor the general public expressed concern about the ability to meet these requirements. In terms of infrastructure, for example, both the St. John's Port Authority and St. John's International Airport Authority are currently expanding facilities in advance of new oil-related demand (while there are also supply base options in Bay Bulls), and St. John's, Mount Pearl and Paradise are actively responding to potential further demand for industrial space. (These issues are considered in greater detail in Chapter 6.)

Similarly, there is a high level of awareness, within the federal government, provincial government, industry and training institutions of the need to plan and prepare for future labour requirements. This is reflected in such reports as *Estimation of Direct Human Resource Requirements, Offshore Exploration and Production, Newfoundland and Nova Scotia* (CAPP 1999) and *Offshore Petroleum Engineering Task Force Report* (Offshore Petroleum Engineering Task Force 1999).

Memorial University of Newfoundland, the CNA, private colleges in Newfoundland and similar institutions elsewhere in Atlantic Canada are paying close attention to, and responding to, such reports and developments in the oil industry. For example, Memorial University has recently developed an ambitious new strategy to become a centre of excellence for oil-related education, training and research and development, with the Faculty of Engineering and Department of Earth Sciences playing major roles (J. Wright, pers. comm.). Also, as further discussed in Section 5.2, the CNA currently offers a range of speciality offshore-related training programs and has a demonstrated ability to respond to industry needs as necessary.

This response will be fuelled both by Project-related labour and industrial requirements and by the range of education and training and research and development initiatives undertaken for the Project.

The above discussion focuses on the direct effects of White Rose on business and employment. In addition, there will be important secondary, or multiplier, positive effects. As has been demonstrated by the Hibernia project, these can be wide-ranging. The study of Hibernia operations impacts (HMDC 1999) demonstrated the total effects of that project on the economy (including the provincial GDP, personal incomes, consumer spending, employment and migration). It concluded that these effects were large and widely distributed, and that they would be long-term. There is no evidence of negative economic consequences, such as wage or price inflation.

The Hibernia impacts report also concluded that it and the industry as a whole are having a transformative effect. As has been seen above, the new company capabilities and ambitions being created by Hibernia, Terra Nova and other offshore oil projects are not just applicable to the offshore oil industry or limited only to Newfoundland or Canada. Similarly, large numbers of Newfoundlanders have developed skills and capabilities that broaden their prospects and horizons. These projects have made these firms and individuals highly competitive and helped them get other oil work, and employment on projects in other industries, locally, nationally or internationally. Greater competitiveness, increased entrepreneurship, increased confidence in local abilities, and similar changes all contribute to a "snowball" process of cumulative economic growth and development that will help grow and diversify the local economy. As such, the industry is causing changes beyond (and which will outlast) the Hibernia and other offshore projects.

Similarly, new oil industry-related industrial infrastructure is reducing the costs of, and increasing likelihood of, potential Newfoundland benefits from further offshore petroleum projects. Furthermore, the new oil industry-related research, development, education and training infrastructure is creating a centre of excellence and learning in this Province in a range of marine and engineering-related areas. Again, while put in place to support local oil activity, these facilities are increasingly being used to undertake work for clients outside of Newfoundland and outside the oil industry, further developing and diversifying the provincial economy (HMDC 1999).

The Project will further contribute to this growing and increasingly internationally competitive industry, and hence, to the further development and diversification of the Newfoundland economy.

4.3.2.2 St. John's Area

During the development phase of the Project, the St. John's area will see administrative, engineering, training, regulatory, and supply and service activity. This work will have a wide range of positive, economic effects, similar to those experienced during development phases of Hibernia and Terra Nova. The Project will provide considerable opportunities for local businesses. There may also be some fabrication activity. For example, St. John's could be the location of work on sub-sea facilities assemblies, dependent on the success of local companies in bidding for such work.

During the 12 to 14-year operational life of the field, St. John's will be the administrative, engineering, training, regulatory and supply and service centre for the Project. The economic effects will, like those associated with Hibernia and Terra Nova projects, be wide-ranging and almost entirely beneficial. Estimated direct operations employment during the first four to five years of the Project are provided in Table 4.3-2. Of these jobs, the onshore support/administration and helicopter air support positions will be based in St. John's, while other offshore workers may choose to reside here.

Table 4.3–2 Estimated Direct Employment, White Rose Operations Phase

Activity	Estimated Employment
Onshore Support/Administration	45-50
Offshore Production	100
Drilling	150
Marine Support (Supply/Standby Vessels)	30
Air Support	5
Tanker Transportation	40
Total	370-375

Source: Husky Oil 2000b

This Project development and production activity, and associated indirect and induced business and employment effects, will have an important beneficial effect on the St. John's area economy. This will see it building on the contribution Hibernia, Terra Nova and the oil industry generally, is already making to the region (Section 4.2). Any cumulative business and employment effects arising are viewed as positive.

4.3.2.3 Isthmus of Avalon Area

The Bull Arm site in Trinity Bay was originally developed as the construction and fabrication facility for the Hibernia project. Since then it has been used for fabrication of topside modules and components for the Terra

Nova project, and it will be the location of hook-up and commissioning activity. Depending on the facility's success in competitively bidding for project work, the site could be used for similar activity on a White Rose FPSO (or semi-submersible) production system. Specific work that might be undertaken at Bull Arm includes the fabrication/construction of the topsides modules, topsides mounted structures and riser bases. It could also be the site of hook-up and commissioning, and the offshore support base for offshore installation work.

The number of workers involved with the Terra Nova topsides fabrication work at the site has fluctuated, with the peak in 1999 reaching approximately 950. Commissioning of the FPSO, beginning May 2000, will lead to an estimated peak employment of over 1,300 later in the year. Hook-up/commissioning activity will wind-down in early 2001. The White Rose schedule would see development activity following after this wind-down. This is potentially advantageous to Husky Oil if current schedules are maintained, since it means that equipment and skills could be available at Bull Arm, potentially with no need to reactivate the facility and reassemble the required labour force. This will also be beneficial to the Isthmus area, in that it could result in continuity in direct and spin-off employment and business activity related to the Bull Arm facility.

There may also be local business and employment benefits as a result of Project operations. Husky Oil has contracted capacity in the Newfoundland Transshipment Terminal for its Terra Nova crude oil production. The terminal is one of several options for White Rose crude oil production that Husky Oil and Petro-Canada are considering. The proponents may use this facility to transship White Rose oil. This would increase use of this facility above that resulting from Hibernia and Terra Nova-related activity. Such an increase would generate further employment and requirements for goods and services.

It appears unlikely that there will be any significant adverse cumulative effects at Bull Arm resulting from concurrent construction/fabrication of White Rose and other project components. Even if concurrent activity were to be the case, there is sufficient capacity at the site and, depending on project requirements, more than one type of project activity could be accommodated that would increase employment and business benefits in the area.

4.3.2.4 Marystown Area

The Marystown shipyard built a number of components for the current offshore development projects, and has worked on rigs involved in exploration and production drilling, indicating that the area could also be affected by the Project. This might similarly include fabrication/construction work and maintenance of rigs involved in production drilling. The amount of such work, and hence the local business and employment effects, is dependent on the shipyard's success in competitively bidding for Project work. Any such work will provide direct and spin-off benefits to the local economy and reinforce the shipyard's position as an important oil industry facility.

Any cumulative effects will depend on other work that may be ongoing at the same time. The shipyard and Cow Head has sufficient capacity to undertake a number of projects concurrently should this arise. From the perspective of the shipyard's owner, local workers, and the local community, any likely cumulative effects would be beneficial rather than adverse.

4.4 INTEGRATED RESIDUAL SOCIO-ECONOMIC EFFECTS

The types of potential effects by Project phase, the types of action that are appropriate, and potential outcomes against the criteria discussed in Chapter 2 are summarized in Table 4.4-1. For those Project activities and other events where substantial levels of business activity and new employment can be expected, the outcomes will be positive for the economy as a whole, the specific regions, and the workers and businesses involved. No adverse effects are anticipated or mitigative measures suggested, as any changes are within the capacities of the local economies. Rather, Husky Oil's Canada-Newfoundland Benefits approach should enhance and help to maximize these benefits.

Table 4.4–1 Valued Environmental Component: Business and Employment

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction:							
Fabrication of offshore components	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2-3	1/1	R	2
Installation of offshore components	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2-3	1/1	R	2
Operations							
Offshore production/support / service	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2	3/ 3	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents							
Emergency response/support	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2-3	3/2	R	2
Past/Present/Future Projects							
Construction	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2-3	1/ 2	R	2
Operations	Increased business and employment (P)	Implementation of C-N Benefits Plan	1	2-3	3/ 2	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Reversibility:
R = Reversible
I = Irreversible

Socio-economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

N/A = Not Applicable

Residual effects, including cumulative socio-economic effects (after any mitigation and based on the criteria outlined in Chapter 2) are summarized in Table 4.4-2. The Project is expected to add further business and employment benefits to all regions and the Province as a whole. No significant adverse effects are predicted.

Table 4.4–2 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Employment and Business				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects**[1]	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	P	3	3	3
Operations	P	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	P	3	3	3
Project Overall	P	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[1] As determined in consideration of established residual socio-economic effects rating criteria

Monitoring and reporting of Canada-Newfoundland benefits commitments will be undertaken by Husky Oil, as required by the Company and by the C-NOPB. Further details as to the monitoring and reporting of procurement decisions and expenditure and employment levels will be provided in the Canada-Newfoundland Benefits Plan.

5 COMMUNITY SOCIAL INFRASTRUCTURE AND SERVICES

5.1 INTRODUCTION

Local residents value community infrastructure and services in that they contribute to the overall standard and quality of life. This section addresses the potential effects of the Project on community social infrastructure and services, focusing on education, health, security (policing and fire protection) and recreation.

In an overall sense, the Project will generate jobs and business activity that, in turn, will create additional income and taxes. At the same time, it may create increased demands for some services and on some infrastructure. While in some cases, increased demands will have positive effects for example, by generating increased user-pay for underused services and facilities, in other cases they may be adverse. The implications of these changes are largely a function of the existing supply-demand situation for particular services and infrastructure at particular locations. If the supply cannot meet current demands, in terms of the quantity and quality of service that have come to be expected, then any incremental effect attributable to the Project will only exacerbate the situation. Alternatively, if there is unused or underused capacity associated with a service or facility, and the incremental change resulting from the Project does not exceed that capacity, then the Project will have no significant effect. In this Chapter, system capacity is adopted as the benchmark against which Project-related changes are evaluated to determine whether they are significant. If a project-related change results in current system capacity being exceeded (implying that additional capacity or other system changes are required in order to maintain current levels of service), then the effect is considered adverse and significant.

Component fabrication and offshore installation employment is relatively short-term and the potential effects on services and infrastructure are expected to be comparable to those experienced with the Terra Nova project. Activity levels for Terra Nova have been significantly lower than those for Hibernia, and that project was also unproblematic in terms of its effects.

Offshore operations for the White Rose oilfield development will result in long-term employment levels similar to those expected for Terra Nova, but less than those experienced by the Hibernia project. Once again, there is no evidence that the Terra Nova project has had any adverse effects on community infrastructure and services. Whether cumulatively these and other projects and activities have had any significant effects is a further question, examined later in this chapter.

For each infrastructure/service component, this section describes and analyzes the:

- existing socio-economic environment, including
  - the particular environmental assessment boundaries relevant to the social infrastructure and services components discussed in this section,
  - existing conditions with respect to each of these social infrastructure and services components;
- socio-economic effects assessment, including
  - an overview of project-environment interactions,
  - a discussion of socio-economic effects, including cumulative effects,
  - a summary of socio-economic management initiatives to address potential effects; and
- integrated residual socio-economic effects, including
  - a summary of residual socio-economic effects significance by project phase, and
  - a discussion of monitoring and follow-up initiatives.

5.2 EDUCATION

5.2.1 Existing Socio-Economic Environment

5.2.1.1 Assessment Boundaries

The assessment boundaries described in Chapter 2 provide the basis for the focus of the assessment of social infrastructure and services. However, education jurisdiction boundaries differ somewhat and, in the case of primary and secondary education, sub-sets of Education Districts are constructed to match the study areas.

Primary and secondary education in the St. John's area is primarily the responsibility of the Avalon East Education District. This includes communities in the region east of a line from Holyrood, Conception Bay, to St. Vincent's, St. Mary's Bay. In addition, the area is serviced by the Conseil scolaire francophone provincial de Terre Neuve et du Labrador, which has one school. Lakecrest Independent School, St. John's Seventh Day Academy, First Baptist Academy, and St. Bonaventure Academy are private schools, and the Brother T. I. Murphy Centre and the School for the Deaf serve students with particular needs.

The Isthmus of Avalon area is served by nine schools in the Vista District, and three in the Avalon West District. The Marystown area is served by six schools within the Burin District.

5.2.1.2 Existing Conditions

Newfoundland

In recent years, Newfoundland has seen a decline in the number of schools, students and teachers, and in the student-teacher ratio. The total of 343 schools in 1999-00, for example, was a decrease of 155 since 1993-94. The number of full-time primary and secondary school children in 1993-94 was 118,892. This had fallen to 93,957 by 1999-00, a decrease of 21 percent. The full-time teaching force has also declined from 7,699 positions in 1993-94 to 6,453 in 1998-99 (16.2 percent) and the number of substitute teachers declined by 12 percent in the same period. Overall, enrolments continue to decline slightly faster than the number of teachers, hence, the student-to-teacher ratio continues to decrease, albeit at a much lower rate. In 1998-99 it was 1:14.6, compared to 1:14.7 in 1993-94 and 1:17 a decade earlier (Newfoundland and Labrador 1994; 1999).

Post-secondary education is provided primarily through Memorial University of Newfoundland, which has its main campus and a Fisheries and Marine Institute in St. John's, and Sir Wilfred Grenfell College in Corner Brook. In addition, there is the CNA, which was established in 1997 with the reorganization of trades and technology programming in the Province. The College has 18 campuses throughout the Province. There are also 54 registered private training institutions in the Province, the greatest number of which are located in the St. John's area. The private colleges primarily offer vocational training.

St. John's Area

Since 1998, most of the primary and secondary education in the St. John's area has been administered by the Avalon East School Board, which replaced the five school boards that had responsibility under the former denominational system.

In 1998-99, there were 81 schools in the District, of which 74 fell within the St. John's area study boundary. By 1999-2000, this had further decreased to 68 schools in the area. This represents a decrease of 11 schools since 1994-95 and reflects changing demographics and the consolidation process under the new system. For example, there were 31,745 primary and elementary students in the St. John's area in 1998-99, a decrease of 4.8 percent since 1994-95, which in turn was a decrease of 5.1 percent since 1988-89. The 1998-99 enrolment in the Francophone school was 54, in private schools 159, and in other schools 145 (Newfoundland and Labrador 1995; 1999).

Statistics on school capacity are not available. Prior to the recent reorganization, enrolments had declined and the number of schools had remained relatively constant, suggesting that there was surplus capacity and that this was increasing over time. Since 1998, additional school closures have eliminated some of that spare capacity, but overall supply still exceeds demand.

Post-secondary education in the St. John's area is provided through Memorial University of Newfoundland, the four campuses of the CNA, and 20 private training institutions.

Memorial University undergraduate enrolments fell from 15,491 in 1992, to 12,583 in the fall of 1999. The general decline in enrolment was halted in 1999, with a small increase recorded over 1998. Overall, graduate enrolment at the St. John's campus increased between 1992 and 1999 from 1,179 to 1,608, peaking in 1997 at 1,668 (Memorial University 1999).

The CNA offers a range of vocational and technical training. The trades certificate programs run for one year, while the technology, business and applied arts diploma programs range from two to three years in length. Evening and apprenticeship programs are also offered. The number of day students at the college has fluctuated in recent years. From 1992-93 to 1994-95, numbers increased from 4,281 to 4,874, after which there was a decline to 2,800 in October 1995 (Petro-Canada 1995). Since then, numbers have stabilized and registration in the fall of 1999 was approximately 3,000 (D. Feltham, pers. com.).

Isthmus of Avalon Area

In 1998-99, there were 12 primary and secondary schools in the area, compared with 14 in 1993-94. In 1993-94, there were 3,572 students in Grades K-12, while in 1998-99 there were 2,719, a decrease of 23.9 percent (Newfoundland and Labrador 1994; 1999).

Marystown Area

In 1998-99, there were six primary and secondary schools in the Marystown area, compared with 10 in 1993-94. In 1998-99, total student enrolment was 2,423, compared with 3,067 in 1993-94, a 21 percent decrease (Newfoundland and Labrador 1994; 1999). The CNA has a campus in Burin.

5.2.2 Socio-Economic Effects Assessment

5.2.2.1 Project-Environment Interactions

Potential project-environment interactions are examined by Project activity phase and by area. Within each area, effects are considered in terms of their demand implications. Demand is further subdivided into direct demand (from the Project itself) or indirect demand (from the economy in general). Potential interactions are summarized in Table 5.2-1.

Table 5.2–1 Project-Environmental Effects Interaction Matrix Community Social Infrastructure: Education

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication			X		X		X	
Field Development/Installation			X					
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events								
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas
Dd = Direct Demand
Di = Indirect Demand

5.2.2.2 Socio-Economic Effects

Newfoundland

Project effects on education at the provincial level will be limited to post-secondary training. The labour requirement for the Project is summarized in Chapter 4 of this report. There is already a substantial pool of trained and experienced labour; however, training of new entrants to the industry and upgrading of those already in it will continue through such programs as CNA's Petroleum Engineering Program in St. John's or its Contract Training programs at Seal Cove and elsewhere in the Province. Demands from the Project will be different and less than those from Hibernia, and similar to those from Terra Nova. In both cases, project-related demands have been accommodated without problem.

Cumulative effects through overlap with the Terra Nova construction/installation are unlikely, given current schedules (see Chapter 4). Training associated with the operations phases of Hibernia and Terra Nova has proceeded in a sequential fashion without any serious overlap issues. Other major projects, such as Churchill River Project and Voisey's Bay Mine/Mill, are unlikely to occur at the same time as White Rose given current expected schedules and will require somewhat different skill sets. At this time, no problems are anticipated to arise from the Project itself, or from cumulative activity, to which provincial post-secondary institutions could not respond.

St. John's Area

The Hibernia SEIS (Mobil 1985) predicted that St. John's area schools would be able to accommodate any demands resulting from demographic changes associated with that project. In fact, the population increase resulting from that project was less than anticipated and there was no significant effect on schools. Consistent with the findings of the Terra Nova SEIS (Petro-Canada 1995), there is no suggestion that smaller project has had any specific effect either. Since the fall of 1998, the implications of changes to the organization and administration of the provincial education system have been the primary focus of attention, rather than any effects associated with offshore development or other contributors to economic growth.

The effects of Hibernia on post-secondary institutions in St. John's were not monitored, but given the limited demographic impacts and declining enrolments, there is no evidence that they placed any critical new demands on these institutions. One exception was the Petroleum Engineering Program at the former Cabot College (now part of CNA), which saw increased demands during the Hibernia construction phase. Since then, demand for this program has continued, and enrolment (24 students per year in the three-year program) is fully subscribed and there is a waiting list.

Through its Contract Training Program, the former Cabot College provided training and upgrading in various trades required for the Hibernia project. Between 1991 and 1995, 2,463 people received training in programs developed by the College (Hedderson Consulting 1995). These programs were outside of the regular programs offered by the College and did not affect regular programs. Contract training is in response to industry needs and has changed since the completion of Hibernia. Current (Winter 2000) programs include petroleum technology, offshore well-control certification and entry level pre-employment for floorhands. The College continues to monitor industry needs and feels confident it can deliver appropriate programs as required (W. Whalen, pers. comm.).

The Terra Nova employment requirements were quite different for those of Hibernia. Employment in the St. John's area has been associated, for example, with project management and procurement, and subsea equipment fabrication. As a smaller project, and coming after Hibernia, training requirements were easily addressed by Petro-Canada in conjunction with local institutions. The White Rose oilfield development is similar in design to Terra Nova and is not expected to have any substantially different types of effects during the construction/installation or operations phases.

When all three projects are in operation, there will be a large workforce located in the St. John's area but any increased cumulative demand on the education system is unlikely to be problematic as the changing demographics of the area continue to lead to a reduced or, at best, stable (in most cases, at lower levels than the past), demands for services.

Isthmus of Avalon Area

The Hibernia SEIS (Mobil 1985) forecast that the project would result in a small increase in the school-age population of the Isthmus Area, but that the existing system would be able to accommodate it. In the April-June 1994 quarterly report of the Hibernia Construction Sites Environmental Management Committee, it was estimated that in-migrant children made up only 1 percent of the 1993-94 enrolment (HCSEMC 1994).

Effects were not, however, experienced uniformly throughout the region. Balbo Elementary in Shoal Harbour experienced the greatest effect, with between 40 and 60 Norwegian children, mostly in the kindergarten age group, attending the school in the 1991 to 1995 period. This required an extra half-time teaching unit for this age group and the provision of Norwegian teachers to provide Norwegian language instruction. With the completion of the project, these demands were eliminated.

The Terra Nova project has not had the same effects. Peak employment at Bull Arm in 1999 was in the order of 950. Workers either commuted from their home locations on a daily basis or found accommodations locally.

There has generally been no temporary in-migration of foreign workers and their families and consequently, no direct effects on the education system as in the Hibernia case.

This is illustrated by data from Balbo Elementary. For the 1999-2000 school year, enrolment at this school was predicted to be 392 children, but the actual enrolment was only 376 (A. Windsor, pers. com.). With the arrival of the Terra Nova FPSO at Bull Arm in late May 2000, the associated increase in employment will bring workers to the area. However, many of the specific tasks are likely to result in only short-term employment, with the result that little in-migration of workers and families is expected and no effect is expected on schools in the area. Likewise, no cumulative effects are anticipated given the likely sequencing of future offshore development and the potential use of Bull Arm.

Marystown Area

No specific data have been compiled for the Marystown area to indicate the effects of the Hibernia or Terra Nova projects on the school population, or the education system generally. However, this has not been a matter of concern as declining enrolments indicate that capacity is not an issue. White Rose is not expected to generate any demands that the existing system could not accommodate and no significant cumulative effects are anticipated.

5.2.3 Integrated Residual Socio-Economic Effects

Through its Canada-Newfoundland Benefits Plan, Husky Oil will actively promote the employment and training of Newfoundlanders and Labradorians. Insofar as such training will affect the post-secondary components of the provincial system, the outcomes should be beneficial or positive for those trained and for the individuals and institutions providing the training. The Hibernia and Terra Nova projects demonstrated that local institutions can provide much of the required training, and White Rose is not expected to be any different in this regard. No significant adverse effects on the primary and secondary elements of the education system are expected either from the White Rose Project itself, or cumulatively in concert with other projects.
The types of effects anticipated by project activity phase, types of mitigation appropriate, and potential outcomes against the criteria discussed in Chapter 2 are summarized in Table 5.2-2.

Significant predicted outcomes (after mitigation strategies are taken into consideration) are indicated in Table 5.2-3. The conclusion reached is that there will be no significant adverse or negative effects of the Project on education infrastructure or services, rather, any effects should be positive.

No formal monitoring or follow-up is anticipated, beyond the normal processes that post-secondary institutions follow in tracking and anticipating demand for existing and potential offshore-related courses and programs.

Table 5.2–2 Valued Environmental Component: Community Social Infrastructure - Education

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction							
Fabrication of offshore components	Training of provincial workforce (P)	Post-secondary institutions plan to meet industry needs	1	2-3	1/1	R	2
Installation of offshore components	Training of provincial workforce (P)	Post-secondary institutions plan to meet industry needs	1	2-3	1/1	R	2
Operations							
Offshore production/support/service	Training of provincial workforce (P)	Post-secondary institutions plan to meet industry needs	1	2-3	3/3	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support	Training of provincial workforce (P)	Post-secondary institutions plan to meet industry needs	1	2-3	3/3	R	2
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Training of provincial workforce (P)	Post-secondary institutions plan to meet industry needs	1	2-3	3/2	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

Table 5.2–3 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Education				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects**	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	P	3	2	3
Operations	P	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	P	3	3	3
Project Overall	P	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[1] As determined in consideration of established residual socio-economic effects rating criteria

5.3 HEALTH AND COMMUNITY SERVICES AND INFRASTRUCTURE

5.3.1 Existing Socio-Economic Environment

5.3.1.1 Assessment Boundaries

Health and community services in Newfoundland and Labrador are administered by the provincial Department of Health and Community Services. While "health" is considered in a holistic fashion and comprises more than just medical services, administratively there are two main areas of jurisdiction. Since 1993, six Institutional Health Boards have been responsible for providing institutional medical services related, for example, to general and speciality medical and mental health. Two other Integrated Boards (Labrador and the Grenfell Regional Health Services Board) oversee the provision of both these institutional services and health and community services. In the areas covered by the Institutional Boards, health and community services are administered by the Health and Community Services Board. In addition there is a regional Nursing Home Board in St. John's.

The mandate of the Health and Community Services Board (and that of the Integrated Boards) includes provision of services in the following areas:

- health promotion;
- disease prevention;
- child welfare and community corrections;
- family and rehabilitative services;
- addictions; and
- mental health and continuing care.

Given the nature of these services and their target populations, most will not be affected by White Rose. For example, assessments of the Hibernia and Terra Nova projects predicted that services to the disabled, seniors, child welfare and youth corrections would directly experience few, if any, Project-related effects. There have been no indications to the contrary. Hence, the focus here is on institutional medical services, where there is a greater potential for project-service interaction.

At the same time, the nature of offshore rotational work arrangements may have implications for the health and well-being of workers and their families. This is an issue, raised in the public consultation process, that cuts across the broad spectrum of health and community services.

The geographic areas administered by the Institutional Health Boards differ from the study areas described in Chapter 2 of this SEIS. To maintain maximum comparability, primary attention is given to those facilities and services located within the study areas wherever possible; however, in many cases the study areas are subsets of larger administrative units.

For institutional health services the administrative units are:

- Newfoundland - the Province as a whole;
- St. John's Area - the area served by the Health Care Corporation of St. John's and the St. John's Nursing Home Board;
- Isthmus of Avalon area - primarily served by the Peninsulas Health Care Corporation; and
- Marystown area - served by the Peninsulas Health Care Corporation.

5.3.1.2 Existing Conditions

Newfoundland

Annual total health care expenditure in the Province was forecast to be $1,411 million in 1999, up from $1,270 million in 1995. In 1997, 12.6 percent of the GDP was allocated to health expenditures, which is a greater share than any other province, and compares to 8.9 percent for Canada as a whole (National Health Expenditures Database 2000).

There are 36 hospitals and health care centres and 19 nursing homes in the province, which in 1999 provided a total of 1,808 acute care beds and 2,951 long term care beds (Department of Health and Community Services 2000a). The level of service in the Province, as defined by the number of nurses and doctors per capita, is comparable to other provinces in Canada.

The number of physicians in the province has declined over the 1989 to 1998 period (Table 5.3-1), but the overall physician-to-patient ratio has remained fairly stable since 1993, as the decrease in the number of physicians has been matched by the decline in population. The type of physician has changed, however, in that there are now fewer general/family practitioners (1.1 per 1,000 in 1994, 1.0 in 1998) and more specialists (0.58 per 1,000 in 1994, 0.68 per 1,000 in 1998) (Southern Medical Database 2000).

The number of registered nurses peaked in 1992 at 5,372 and subsequently declined. By 1998, however, numbers had almost returned to 1992 levels. During the 1989 to 1998 period, the registered nurse-to-population ratio showed an overall increase from 8.6 per 1,000 to 9.79 per 1,000 (Department of Finance 2000b).

Table 5.3–1 Physicians and Registered Nurses per 1000 Population Newfoundland 1989 -1998

Year	Physicians[1]	Registered Nurses	Per 1000 Population	
			Physicians	Registered Nurses
1989	1,028	4,959	2.02	8.60
1990	980	5,179	1.95	8.96
1991	969	5,301	1.91	9.15
1992	952	5,372	1.89	9.26
1993	971	5,147	1.67	8.87
1994	968	5,178	1.68	9.01
1995	940	5,203	1.66	9.16
1996	928	5,261	1.66	9.38
1997	932	5,210	1.68	9.40
1998	926	5,340	1.70	9.79

[1] Physicians active at year end.

Source: Department of Finance 2000b

The challenges facing medical care in Canada and the Province are of considerable public concern. In Newfoundland and Labrador, concern has been expressed about the limited number of nurses, and of physicians in some speciality areas, and the availability of nurses and family physicians in rural areas, as they limit patient access to, and potentially reduce the quality of, medical services. A shortage of nurses, for example, can affect the number of beds that can be kept open, and the ability of hospitals to provide elective surgery in particular.

The issue of nurse shortages is currently under review by government. The specific issue of the availability of nurses in rural areas, for example, is in part being addressed through the nurse-practitioner program. Since the program began in 1997, 25 nurse-practitioners have graduated and are in the work place, and the 2000 class is about to graduate.

Of direct relevance to the offshore industry, is the hyperbaric facility constructed in 1988. Located at the Health Sciences Centre in St. John's, it currently provides emergency treatments for decompression sickness and air embolism resulting from diving accidents and is an example of one of the socio-economic effects of the developing offshore industry.

St. John's Area

The St. John's area has a number of acute and long-term care facilities and one health care centre. As of March 2000, the Health Care Corporation St. John's provided 899 acute-care beds in seven facilities. The total number of acute-care beds has declined slightly from 909 in 1994-95 and the number and location of beds continues to change with the consolidation of facilities within the area.

Long-term care facilities in the area provided a total of 1,337 beds in March 2000; 283 in four hospitals and health centres and 1,054 in six nursing homes. This compares with 1,073 in 1994-95. The only health care centre in the area is the Dr. Walter Templeman Centre on Bell Island. It provides 8 acute-care and 12 long-term beds. In 1994-95, it provided 6 acute-care and 14 long-term beds.

St. John's also has one psychiatric institution, the Waterford Hospital, which has 92 acute-care and 127 long-term care beds. Other hospitals provide some psychiatric care (Department of Health and Community Services 2000a).

The need for physicians in an area is strongly related to the demographic characteristics of the area and as such requires periodic review. There are no current available data regarding needs, but in 1999, a Provincial Human Resource Planning Committee, whose membership includes representatives from government, provincial health care boards, unions and other stakeholders, was established to review this and related human resource issues.

Isthmus of Avalon Area

The Dr. G. B. Cross Memorial Hospital in Clarenville serves the Isthmus area. It has 51 acute-care and 14 long-term beds, up from 48 acute-care and 9 long-term care beds in 1994-95. It provides a range of medical speciality services to the area. There is no psychiatric institution in the area. While the Cross Memorial Hospital does not provide formal psychiatric in-patient services, patients can be admitted to the medical-surgical service. In June 2000, there were nine family physicians practising in Clarenville and two in Arnold's Cove.

Marystown Area

The Marystown area has one acute-care facility, the Burin Peninsula Health Care Centre, which has 54 acute-care beds. This is down from 70 beds in 1994-5. There are no long-term care beds in the area. Speciality psychiatric institutions and services are not available at the Centre, however, patients with psychiatric disorders are admitted to the medical-surgical service when necessary. In June 2000 there were 14 family physicians practising in the Area.

5.3.2 Socio-Economic Effects Assessment

5.3.2.1 Project-Environment Interactions

Potential project-environment interactions with respect to medical services and infrastructure are summarized in Table 5.3-2. Project activities will result in an increased workforce in the Province and the study areas, although some of this will result from increased labour force participation rather than population growth. Some of that workforce and their families will, at times, require medical treatment and other services. Where the workers and their families are in-migrants to the Province, this will represent an increase in demands on the Provincial system as a whole. Where in-migrants move from elsewhere within the Province, overall demand will remain the same, but will shift geographically. At the same time, migration to the Province will add to the tax-base and indirectly help to offset increased costs.

Table 5.3–2 Project-Environmental Effects Interaction Matrix Community Social Infrastructure: Medical Services and Infrastructure

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication			X		X		X	
Field Development/Installation			X					
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events			X		X		X	
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

Demands associated with the construction and installation workforce will be short-term and limited to this phase, while the smaller numbers engaged in operations will have long-term demands. Most demands will be associated directly with the Project, but there will be some cumulative effects associated with the operations phase of Hibernia and Terra Nova, together with other, non-oil, projects. An audit of socio-economic effects of Hibernia concluded that it had not placed any critical burden on the health-care system (Storey et al. 1996). At the same time, there have been some positive cumulative effects with, for example, the continued development of remote trauma medicine capabilities.

Offshore activities to date have not resulted in the rapid lifestyle changes that some originally anticipated, and there appears to have been no associated increase in demands for example, services related to mental health, addictions or sexually transmitted diseases. At the same time, some concern was expressed during the White Rose public consultation process that work patterns which involve extended time away from home and family place stress on workers and their families, which may manifest itself in an increased demand for medical and other health and community services.

There are no recent studies in the Newfoundland offshore to support or refute this. A study of the Newfoundland offshore workforce in 1985 (Storey et al. 1986) concluded that while most workers and families felt positive towards employment offshore and the rewards and family lifestyles that accompanied it, some did not. Of those who did not, it was often the female spouses who were less satisfied or reconciled to their situation than the men. This appeared to be associated with the double burden of adjustment that falls upon them: first, adjusting to the practical aspects of having an "intermittent spouse" (sole source of child care, home care, etc.), and then, to the needs and demands of the spouse during the period onshore. A variety of strategies by both males and females was noted, which provided the basis for a number of recommendations with respect to improving the circumstances of workers and their families.

This study was carried out during the peak of exploration activity in the mid-1980s. Many of the participants were new to the industry, and the industry was relatively new to the idea that work and family life were closely interconnected and that there was an industry responsibility to address issues arising from the work system. Fifteen years later, the industry has matured, as have those who have remained with it over that time. Companies are now cognizant of the need for more careful screening processes for offshore workers and for the need to provide better information to industry newcomers about what they and their families can expect. In addition, employee and family assistance programs are available when required.

5.3.2.2 Socio-Economic Effects

St. John's Area

There have been no specific studies of the issue, but there is no evidence that the Hibernia or Terra Nova projects resulted in substantial new demands for health care services in the St. John's area. The population increases associated with each of these projects has been small and, in the case of Hibernia, less than expected. Generally speaking, incoming workers and their families tend to be relatively young and healthy enough to place relatively low demands on medical facilities and services; if anything, those working are very likely net contributors to the system in terms of taxes paid relative to services used.

While both Hibernia and Terra Nova projects have resulted in a cumulative increase in the number of oil-industry personnel and families in the area, the total increase in the area's population between 1991 and 1996 was very small (1.3 percent), and considerably smaller than previous intercensal growth (see Section 3.3.1), suggesting that there were few cumulative effects evident on the demand side. Of greater importance in recent years has been public concern over a reduction in the supply of services associated with budget cuts.

The Project will result in some in-migration of onshore and offshore personnel. These individuals and their families will have a small incremental effect on the overall demand for medical services over the life of the Project, but if current demographic trends continue, this and other incremental effects will, in total, be less than the growth rates experienced in the 1980s and early 1990s.

Isthmus of Avalon Area

The Hibernia project had few effects on the demand for medical services in the Isthmus area. The Bull Arm work camp had its own medical centre, with ambulances, a doctor and nursing staff. The Terra Nova project has been much smaller and has not resulted in substantial population increase in the area and, consequently, has not substantially affected the demand for services. White Rose, were it to use the Bull Arm facility, is similarly not expected to place critical demands on the system, and no cumulative effects are anticipated.

Marystown Area

The population of the Marystown area declined by 3 percent between 1991 and 1996, to 12,552. Medical services and facilities have also decreased somewhat in recent years, but any White Rose-related work is unlikely to place any substantive incremental demands on the current system. As in the Isthmus area, no significant cumulative effects are anticipated.

5.3.3 Integrated Residual Socio-Economic Effects

The types of effects anticipated by Project activity phase, the types of mitigation appropriate, and potential outcomes against the criteria discussed in Chapter 2 are summarized in Table 5.3-3.

Table 5.3–3 Valued Environmental Component: Community Social Infrastructure – Medical Services and Infrastructure

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction:							
Fabrication of offshore components	Increased demand for medical services (A)	Institutions respond as appropriate/feasible	1	2	1/ 3	R	2
Installation of offshore components	Increased demand for medical services (A)	Institutions respond as appropriate/feasible	1	2	1/ 3	R	2
Operations							
Offshore production/ support/ service	Increased demand for medical services (A)	Institutions respond as appropriate/feasible Proponent monitors and responds to work and family life issues	1 1	2 3	3/ 3 3/ 3	R R	2 2
Decommissioning							
Offshore decommission/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/ support	Increased demand for medical services (A)	Institutions respond as appropriate/feasible Proponent medical and EAP programs	1	2	3/ 3	R	2
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased demand for medical services (A)	Institutions respond as appropriate/feasible	1	2	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

The Project will lead to some increases in demands for medical services, but these are expected to be minimal, given the typical age composition of the workforce (20 to 50) and the fact that operators have established specific medical programs for their operations. There will be some cumulative effects during the operations phase in particular, but the demands from the offshore-related workforce overall are again expected to be small and within the capacity capabilities of the current system.

As noted earlier, there is considerable public concern about the health care system and particularly, the level of federal funding allocated to it. These are issues beyond the scope of this SEIS. Responsibility for the health care system rests with the Health Boards, the Province and, ultimately, the Government of Canada. Husky Oil has no ability or responsibility to address the broader issues beyond ensuring that its operations are safe and its workplaces healthy so as to impose minimal demands on the health care system. The Project and associated direct and spin-off business and employment will, however, contribute to government revenues through resource rents and business and personal taxes and thus indirectly help to support the system. Anticipated residual effects are summarized in Table 5.3-4.

Table 5.3–4 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Medical Services and Infrastructure				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects[1]**	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	NS	3	3	3
Operations	NS	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	NS	3	3	3
Project Overall	NS	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable
[1] As determined in consideration of established residual socio-economic effects rating criteria

Monitoring demand at the institutional level is a provincial responsibility and one that is ongoing at the Health Care Board, Departmental and committee levels. No additional monitoring by Husky Oil is relevant in this regard. However, Husky Oil recognizes its responsibility to its workforce and their families, and will monitor work and related family issues on a periodic basis. Data from this will provide input into a better understanding of the health of its workforce and their families.

5.4 SOCIAL ASSISTANCE AND EMPLOYMENT SERVICES

5.4.1 Existing Socio-Economic Environment

5.4.1.1 Assessment Boundaries

The Department of Human Resources and Employment is the provincial agency responsible for income support through social assistance and employment-related services. Service area boundaries do not necessarily coincide with the study area boundaries in this assessment. The discussion here focuses on the district offices in each of the study areas.

In the St. John's area there is a St. John's Region office, three district offices within the City and others on Bell Island and in Conception Bay South. For the Isthmus of Avalon area, the District Office is in Clarenville, while that for the Marystown area is in Marystown.

5.4.1.2 Existing Conditions

St. John's Area

The demand for social assistance in the area increased substantially in the early 1990s. In 1993, the number of cases was 103,216, which increased to 113,745 in 1994 (10.2 percent). By 1998, however, the number had fallen to earlier levels (104,581) and remained fairly stable through 1999 (105,567), reflecting improved local economic conditions (Department of Health and Community Services 2000b). Between 1990 and 1995, an additional 18 financial assistance officers (now Client Assistance Officers (CAOs)) were hired to accommodate the increase; even so, the average CAO caseload increased from 171 to 188 (Petro-Canada 1995). Between 1995 and 1999, no further CAOs were hired. Current average caseloads average approximately 200 per CAO (B. Mullaly, pers. com.).

Isthmus of Avalon Area

Between 1992 and 1996, the Hibernia Construction Sites Environmental Management Committee monitored demand for social assistance in the Isthmus area. The Committee's quarterly reports showed that from June 1991 to November 1994, the number of social assistance cases was greater than in the same month the previous year (HCSEMC 1994). From November 1994 to December 1999, month-to-month numbers have declined each year (data for some months in 1995 and 1996 are missing but the decrease in the number of cases by month is true for all months and years for which data are available). In total, the number of social assistance cases for Clarenville fell from 11,717 in 1997 to 10,070 in 1998 and to 8,956 in 1999 (Department of Health and Community Services 2000b).

This was explained by local departmental officials as a combination of the result of increased employment levels and out-migration. Employment levels have increased at, for example, the Bull Arm site, the Arnold's Cove fish plant, the Clarenville crab plant, the Jamestown lumber plant and in tourism generally (F. Greene, pers. com.).

Marystown Area

The demand for social assistance services in the Marystown area increased in the 1990s. From 1993 to 1995, the number of cases grew from 11,028 to 12,671 (14.9 percent), and CAO caseloads increased considerably. By 1998, the number of cases had increased to 18,420, but fell to 16,745 in 1999 (Department of Health and Community Services 2000b). Neither the Isthmus nor the Marystown areas have hired any new CAOs since 1995. Increased demands have resulted in caseloads rising in mid-1997 to late 1998 to in excess of 260 to 280 per CAO. With the subsequent decline in demand, caseloads have fallen to approximately 200 per CAO. No single factor explains the changes, but the dependence of the area on the shipyard and the fishery has meant that demands for assistance are closely related to activity levels in these sectors and to decisions with respect to out-migration. As in the Isthmus case, increased out-migration has had the effect of reducing the number of cases (F. Greene, pers. comm.).

5.4.2 Socio-Economic Effects Assessment

5.4.2.1 Project-Environment Interactions

The potential interactions between the Project and the socio-economic environment are illustrated in Table 5.4-1. Individuals and families requiring social assistance and employment support do so for a wide range of reasons. Much of this population will not be able to take advantage of new opportunities presented by the Project itself, where specific education, training and experience may be required. The Project will, however, generate spin-off effects that will provide a broader range of employment opportunities, particularly in the service sector.

Table 5.4–1 Project-Environmental Effects Interaction Matrix Community Social Infrastructure: Social Assistance and Employment Services

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	Dd	Di	Dd	Di	Dd	Di	Dd	Di
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication								
Field Development/Installation								
Operations								
Administration			X	X				
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X	X				
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events								
Past/Present/Future Projects								
Construction								
Operations			X	X				

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas
Dd = Direct Demand
Di = Indirect Demand

Project-environment interactions with respect to these types of community services are, therefore, expected to be of both a direct and indirect nature, primarily experienced in the operations phase and as a result of cumulative effects, and particularly in the St. John's area. The effects may be both positive and negative. They will be positive, in that some individuals may find work, thereby reducing the need for financial support. They will be negative in that any indirect inflationary effects (for example, for rental accommodation) will likely particularly affect those on low incomes and potentially increase demands for income support services.

5.4.2.2 Socio-Economic Effects

St. John's Area

The effects of the Project on social assistance and employment services will likely be small and primarily positive. The Hibernia SEIS (Mobil 1985) discussed concerns that population increases would place additional burdens on an already stressed social services system in the St. John's area. In particular, it was thought that increases in the cost of living would generate new demands for social assistance, especially by those on low and fixed incomes. However, Hibernia-related population growth and inflation were considerably less than expected, and the demands on services resulting from the project proved insignificant.

The number of social assistance cases did increase substantially between 1990 and 1995, but Hibernia was not a factor in this. Social services personnel indicated that the project had very little negative effect on the system rather that it played a positive role by creating employment (Petro-Canada 1995).

To date, the effects of Terra Nova on the St. John's area economy have been small relative to the total size of the economy. Direct employment has reached over 400 persons, compared with 400 to 450 at the same stage for Hibernia, and any effects are expected to be comparable. The effects of the White Rose Project are also expected to be comparable to those for Terra Nova and Hibernia.

The cumulative effects of the three offshore projects plus other developments on the downtown housing market was raised at White Rose public consultation sessions. Property sales and prices have increased in recent years in this area. It was felt that the downtown community was changing as smaller numbers of low-income people were now able to afford to live there.

It is difficult to separate the cause and effect relationships contributing to these changes. Change is attributable to both economic growth and more general demographic and lifestyle changes. The appeal of living downtown now appears to be greater for young professionals and couples, and the increase in the number of condominiums in the area is attracting a wider age range and income spectrum. Some of those moving into the downtown are involved with the oil industry, but many are not, but no data are available to provide any further analysis.

For property owners, retailers, home renovation companies, municipal government, etc., these developments have positive economic effects. For those displaced or otherwise affected, the changes are economically and socially adverse. Where this is the case, agencies with responsibility for social housing and income support may be called upon to assist.

Isthmus of Avalon Area

Increases in demands in the Isthmus area in the early 1990s were attributable to a variety of factors, the most significant being the closure of several fisheries. This placed greater demands on the social assistance program because many people were not eligible for fishery support programs. Another factor was that Clarenville, which has being growing, had attracted a number of in-migrants dependent on social assistance (Petro-Canada 1995).

The decline in the number of cases since 1994 is attributed to generally improving economic conditions in the area and out-migration (see Section 5.4.1).

The Hibernia construction project created some minor problems in that, for a short period, there was insufficient on-site accommodations, which had the effect of driving up costs of local rental accommodations. This required some minor expenditure on the part of what is now the Provincial Department of Human Resources and Employment. However, an audit of Hibernia's overall socio-economic effects concluded that 'there is no evidence that the project has had any significant positive or negative effect on social services' (Storey et al. 1996).

Terra Nova, as a much smaller project, has not had the same effects, positive or negative. In the light of experience with this project, concerns expressed at the public consultation sessions for White Rose were mostly focussed on how to better capture the benefits of the Project within local communities and how to minimize any negative effects on workers and their families. The implications for social assistance programs were not raised as important concerns.

Given the sequencing of future offshore projects, few, if any, cumulative effects are expected. However, should they occur, they would likely be beneficial for the area.

Marystown Area

In 1995, Department of Social Services staff in the Marystown area reported that, while there had been increasing annual local demands for social assistance for several years, there was little direct relationship to the Hibernia project. There were some short-term increases in local rents that could perhaps be attributed to the project that may have affected people on low incomes, but more generally, the project had positive direct and indirect benefits.

The Terra Nova project has had only minor effects on Marystown. The effects of the White Rose Project will depend on contracts with the Marystown shipyard. However, no negative effects on services were anticipated by those involved in the public consultation process nor are they predicted based on other experiences. No cumulative effects are anticipated.

5.4.3 Integrated Residual Socio-Economic Effects

The types of potential effects by Project phase, the types of mitigation or action that is appropriate, and potential outcomes against the criteria discussed in Section 2 are summarized in Table 5.4-2. The St. John's area, and in particular the City of St. John's, is the most likely to experience effects, but no significant adverse effects are predicted and some benefits are expected.

Table 5.4–2 Valued Environmental Component: Community Social Infrastructure – Social Assistance and Employment Services

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction:							
Fabrication of offshore components	Decreased demands for services (P)	Monitoring/ action by responsible authorities	1	2	1/3	R	2
Installation of offshore components			N/A	N/A	N/A	N/A	N/A
Operations							
Offshore production/ support/service	Increased demands for services (A) Decreased demands for services (P)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2
Decommissioning							
Offshore decommissioning / support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support			N/A	N/A	N/A	N/A	N/A
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased demands for services (A) Decreased Demands for services (P)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

The same conclusion is reached in considering the cumulative effects of population growth associated with the direct and indirect employment in three major oil developments, and other economic activity. The effects on social assistance and related services are not expected to be significant in an adverse sense and there will be some positive effects. Furthermore, the Project and associated direct and spin-off business and employment will contribute to government revenues through resource rents and business and personal taxes.

These conclusions are summarized in Table 5.4-3, based on the criteria outlined in Chapter 2. No formal Project monitoring is recommended. The provincial department responsible for social assistance and employment support programs has in place mechanisms to assess and address program needs as they arise.

Table 5.4–3 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Social Assistance and Employment Services				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects[1]**	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	P	3	3	3
Operations	P	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	P	3	1	3
Project Overall	P	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

N/A = Not Applicable

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[1] As determined in consideration of established residual socio-economic effects rating criteria

5.5 SECURITY AND SAFETY: POLICING AND FIRE PROTECTION

5.5.1 Existing Socio-Economic Environment

5.5.1.1 Assessment Boundaries

Newfoundland is policed by the Royal Newfoundland Constabulary (RNC) and the Royal Canadian Mounted Police (RCMP). Within the study areas covered by this report, the RNC has jurisdiction over the St. John's area, while the Isthmus of Avalon and the Marystown areas fall under the jurisdiction of the RCMP.

Both full-time and volunteer fire-fighters serve the Province. While detachment and fire department administrative and data boundaries do not coincide with the study area boundaries, this is not anticipated to affect the following analysis.

5.5.1.2 Existing Conditions

Newfoundland

Newfoundland has the lowest requirement level for policing in Canada, reflecting the Province's relatively low crime rates. In 1999, the overall officer-to-population ratio was 142 officers per 100,000 population, compared to a national average of 181/100,000. Of the total of 767 officers, 311 were RNC and 456 were RCMP. Over the 1991 to 1999 period, the total number of officers declined by 16.4 percent (CCJS 2000).

In March of 2000, 303 fire departments served the province, down from 312 in 1993. According to the Fire Commissioner's Office, the present number and qualifications of fire-fighting and prevention personnel are adequate to meet existing needs (P. Howlett, pers. com.).

St. John's Area

In 2000, 311 RNC personnel served the St. John's area. This is an increase over 1995, when there were 256 (Petro-Canada 1995). The changes in part reflect the need to serve a larger population in areas of the CMA, such as Conception Bay South. They do not reflect increases in criminal activity, there have been no substantial changes in the amount or type in the area over the past decade (J. Browne, pers. com.).

Fire protection services are provided by the St. John's Regional Fire Department and volunteer fire departments in Pouch Cove, Torbay, Bell Island and Conception Bay South, Portugal Cove/St. Phillips, and Outer

Cove/Logy Bay/Middle Cove. Fourteen fire stations and approximately 355 firefighters serve the area, an increase of approximately 55 since 1995 (P. Howlett, pers. com.).

Isthmus of Avalon Area

Fifteen RCMP officers serve Clarenville and the surrounding area, including most of the study area. This represents an officer-to-population ratio of approximately 1:1,408 (RCMP 2000). The number of officers is the same as in 1995 but population growth over the last decade has reduced the ratio somewhat over time. Notwithstanding the presence of the Hibernia and Terra Nova projects at Bull Arm, there have not been any substantial changes in policing requirements in the last decade. Criminal code offences in the larger Clarenville-Bonavista District did, in fact, increase as Hibernia construction employment was winding down, though no causal relationship is suggested, but by 1998, the number of offences was lower than 1995 levels (Table 5.5-1).

Table 5.5–1 Total Criminal Code Offences, Clarenville-Bonavista Area

Year	1995	1996	1997	1998
Total Offences	1,031	1,287	1,316	991

Source: RCMP 2000

The Isthmus of Avalon area is served by five fire departments in Sunnyside, Come By Chance, Arnold's Cove, Hillview and Clarenville, with an average of approximately 25 firefighters (P. Howlett, pers. com.).

Marystown Area

The Marystown area is served by a detachment of 13 officers, down from 15 in 1995, which represents an officer to population ratio of approximately 1:1,350 (RCMP 2000). This ratio is down somewhat from an estimated 1:1,200 in 1995, but has been sufficient to meet local needs. The RCMP reported that the area has few crime problems and that Hibernia-related activity had no effect on policing requirements (Petro-Canada 1995). As was the case in the Clarenville-Bonavista area, criminal code offences in the larger Marystown-St. Lawrence area increased in 1996 and 1997, but decreased in 1998 (Table 5.5-2).

Table 5.5–2 Total Criminal Code Offences, Marystown, Grand Bank, St. Lawrence Area

Year	1995	1996	1997	1998
Total Offences	1,301	1,408	1,482	1,289

Source: RCMP 2000

Fire protection in the Marystown area is provided by volunteer departments in Burin, Lewin's Cove, Winterland, Frenchman's Cove and Garnish, and by a composite fire department in Marystown.

5.5.2 Socio-Economic Effects Assessment

5.5.2.1 Project-Environment Interactions

The potential Project-environment interactions with respect to security and safety-related issues by Project phase are indicated in Table 5.5-3. As with any other industrial or business activity, there is a potential for Project-related activities to require policing or fire protection services. Construction-related demands could occur in St. John's, the Isthmus or Marystown areas if the infrastructure in these areas is used. During the operations phase, St. John's will be the primary area affected. Malfunctions, accidents or unplanned events might involve both the police and fire service, depending on the nature and location of the event. Any cumulative effects are likely to be associated with ongoing operations in the St. John's area.

Table 5.5–3 Project-Environment Effects Interaction Matrix Community Social Infrastructure: Policing and Fire Protection Matrix

Project Activities and Physical Works	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
	Dd	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication			X		X		X	
Field Development/Installation			X		X		X	
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Support			X					
Offshore Production/Marine Support			X					
Tanker Transport					X			
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events			X		X		X	
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

5.5.2.2 Socio-Economic Effects

Newfoundland

During the public consultation process for the Hibernia project, concerns were expressed that it might lead to increases in organized and white-collar crime, drug-trafficking and prostitution. None of these concerns proved to be justified and the concerns disappeared over the life of the project (see Table 2.2-1). The RNC and RCMP reported that neither the type nor the rate of criminal activity increased substantially over the life of the project and any changes in policing requirements were not attributable to it. Similarly, the project had no effect on fire protection at the provincial level. The Terra Nova SEIS (Petro-Canada 1995) forecast that much smaller project would also not have any significant effect, and this has proven to be the case thus far. The same is expected to be the case with White Rose.

St. John's Area

There has been no suggestion or evidence that Hibernia or Terra Nova have affected the nature or level of crime, or the demands for policing services or fire protection, in the area. White Rose, even when the cumulative effects of multiple project operations are considered, is not expected to change this.

Isthmus of Avalon Area

The potential effect on crime was a concern when Hibernia construction activities were first proposed for the Isthmus area in the mid-1980s and when construction began in 1990 (Table 2.2-1). There was a fear that an influx of construction workers would increase prostitution, drug-related disturbances, rape and sexual harassment. The self-contained workcamp and camp security arrangements at the Bull Arm site were intended, in part, to address these concerns. These avoidance/mitigation strategies proved effective. The RCMP reported no Hibernia-related effects on crime and by 1996, local residents were no longer reporting that crime was a concern for them with regards to the project (Jones 1998).

The Terra Nova project has also used the Bull Arm site. The number of employees has been much smaller and workers have either commuted daily from their homes or found accommodations in the area. The RCMP reports no substantive effect on crime. An increase in employment is expected during the outfitting of the Terra Nova FPSO, but few concerns are anticipated with respect to the potential effects on crime in the area. White Rose is not expected to have any different effects.

The Bull Arm site has fire-fighting capacity and is not solely dependent on community services, though they would undoubtedly respond if called upon to assist. Projects there have, to date, not had any effects on local fire services. This will remain the case should any White Rose activity occur there.

The construction and operation of the Newfoundland Transshipment Terminal at Whiffen Head has been another major development in the area. While emergency response capabilities were raised as a concern by area residents, crime or concerns about demands on local fire protection services were not (JWEL 1996). The sequencing of recent projects has resulted in little concern over any cumulative effects and none is anticipated during the White Rose Project if Bull Arm is used.

Marystown Area

Hibernia-related work was centred on the Marystown shipyard and Cow Head. The work was completed primarily by the existing, locally-resident workforce and there were no effects on policing requirements. Terra Nova-related work has been of a much smaller and comparatively short-term nature. No effects on policing are reported. As with the other study areas, the Hibernia and Terra Nova projects had no effect on fire protection services in the area, and the same would be the case given any White Rose activity. No adverse cumulative effects are anticipated.

5.5.3 Integrated Residual Socio-Economic Effects

The types of effect anticipated by project phase and mitigation measures, and potential outcomes against the criteria discussed in Chapter 2 are summarized in Table 5.5-4. None of these project-related or cumulative predicted outcomes are considered significant effects (Table 5.5-5).

Data on events and needs are collected on a regular basis by the relevant policing and fire-protection authorities as part of their normal mandate and planning activities. No additional monitoring or follow-up is anticipated or proposed.

Table 5.5–4 Valued Environmental Component: Community Social Infrastructure – Policing and Fire Protection

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction							
Fabrication of offshore components	Increased demands for services (A)	Monitoring/ action by responsible authorities	1	2	1/ 3	R	2
Installation of offshore components	Increased demands for services (A)	Monitoring/ action by responsible authorities	1	2	1/ 3	R	2
Operations							
Offshore production/support/ service	Increased demands for services (A)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support	Increased demands for services (A)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased demands for services (A)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

Table 5.5–5 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Policing and Fire Protection				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects[1]**	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	NS	3	3	3
Operations	NS	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	NS	3	3	3
Project Overall	NS	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[1] As determined in consideration of established residual socio-economic effects rating criteria

5.6 RECREATION SERVICES AND FACILITIES

5.6.1 Existing Socio-Economic Environment

5.6.1.1 Assessment Boundaries

Recreation implies refreshment of the individual, both mentally and physically, through relaxation and enjoyment. The range of methods used by people to achieve this end is almost infinite and could include reading a book, attending a concert, walking in the woods or playing golf. The range of possibilities is too large to assess in any comprehensive manner. The focus here is limited to recreation activities which have a sports focus, not because it is believed that this is necessarily the most important type of recreation, but because it does involve a broad spectrum of the population in terms of age, gender, and income levels, and can be illustrative of the potential effects that offshore development could have on this type of social activity.

A limitation of this focus is that a number of particular, but significant, recreation-related effects of offshore development are not captured. For example, many large corporations support local arts and cultural activities that provide a source of recreation for residents. HMDC, for one, has been a sponsor of the Newfoundland Symphony Orchestra. In addition, it may fail to capture the involvement of newcomers as performers and participants in various activities that may enrich the experience for everyone involved.

Responsibility for sports-related recreational services and facilities lies with both the public and private sectors. The cities of St. John's and Mount Pearl and many towns within the study areas have their own recreation departments and facilities. Private organizations and operators offer team sports, golf, personal fitness and other sporting activities. For illustrative purposes, this analysis assesses municipal facilities and services in the study areas. In the St. John's area, primary attention is given to the cities of St. John's and Mount Pearl. In the Isthmus of Avalon area, most of the larger public recreational facilities are in the Clarenville area, while in the Marystown area, they are in Marystown itself. The focus of the analysis is primarily on these types of facilities which service their wider areas.

5.6.1.2 Existing Conditions

St. John's Area

St. John's and Mount Pearl have numerous recreation and leisure facilities capable of accommodating a wide range of activities. In St. John's, indoor activities can be accommodated at, for example, the H.G.R. Mews Community Centre, the St. John's Recreation Centre at Buckmaster Circle, and the Wedgewood Park and Goulds Recreation Centres. There is also Memorial Stadium, soon to be replaced by a new stadium and civic centre, and there are winter (for example, skiing) and summer (for example, swimming) facilities and programs at Rotary, Bannerman, Bowring and Victoria Parks. In addition, the City has responsibility for numerous soccer, softball, baseball, tennis and playground facilities.

Mount Pearl also has a range of facilities, including the Glacier (arena), the Smallwood Drive RecPlex (Smallwood Arena, soccer fields, baseball), the Pearlgate Track and Field complex, the St. David's Tennis Complex, the Smallwood Pool, Pearlgate Lanes Bowling, the Reid Community Centre, the Kenmount Park Neighbourhood Centre, a golf driving range and a number of parks, playgrounds and tennis courts. As in St. John's, there is also an extensive walking trail system.

Demographic and lifestyle changes are changing the demand for some types of recreational facilities and programs. Using Mount Pearl as an example, as the community matures, the proportion of families with young children is falling, and demand is beginning to shift away from the younger person-oriented team sports. The older population and lifestyle changes have, for example, contributed to the increased use of the walking trail system and increased the demand for personal fitness activities. Currently, the Pool and the Reid Centre fitness facility are used to full capacity, and there is a demand for some new types of facilities, including a curling club (S. Jewczyk, pers. comm.).

Isthmus of Avalon Area

While the Isthmus area contains a range of recreational facilities, many of the larger ones are found in the Clarenville-Shoal Harbour area. These include a stadium, softball fields, a sports complex, a community centre, gymnasium, tennis courts, a bowling alley, ski facilities and playground areas. The Clarenville SportsPlex, built in 1998, contained a pool, weight room and squash courts. The complex closed in late 1999, with building maintenance difficulties cited as the reason. There are also a number of hiking trails in the area, including the 5-km Rotary Trail, and the Bear Mountain Hiking Trail is now under construction (G. Gosse, pers. com.).

Marystown Area

There are various recreational facilities in the Marystown area, supporting such activities as soccer, softball, ice sports, tennis, swimming, basketball, beach volleyball, skateboarding and floor hockey. Marystown and Burin have the widest range of facilities and service a number of the smaller communities.

The Marystown Arena is open year-round and serves the Burin Peninsula from Terrenceville to St. Lawrence. The Ville Marie Swimming Pool operates on a seasonal basis, offering Red Cross and Lifesaving swimming lessons, swims and a variety of water fitness and recreation programs. The facilities and programs appear to satisfy the needs of local residents (T. Mallay, pers. comm.).

5.6.2 Socio-Economic Effects Assessment

5.6.2.1 Project-Environment Interactions

Potential Project-environment interactions are indicated in Table 5.6-1. While many Hibernia workers used recreation facilities in the Isthmus area during the project, the smaller number of workers involved with Terra Nova and the comparatively short construction period has not had the same effect. As White Rose is of comparable scale, potential effects are expected to be limited to the operations phase.

Table 5.6–1 Project-Environmental Effects Interaction Matrix Community Social Infrastructure: Recreation

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication								
Field Development/Installation								
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events								
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

Effects on recreation systems may be both adverse and positive. Where additional demand exceeds the capacity of a particular facility or program, then access to the program may be reduced for all or, because of overcrowding or similar factors, the level of enjoyment of the activity may be reduced. At the same time, participation of newcomers may make activities more viable, and the introduction of more or new people may enhance the enjoyment of the activity for all.

5.6.2.2 Socio-Economic Effects

St. John's Area

The Hibernia SEIS (Mobil 1985) predicted that project-related demographic changes would not result in any substantial increases in demand on recreational services and facilities. There has been no evidence to contradict this. The population of the area has grown only slightly in the last decade and any project-related demands have been easily absorbed. Of greater importance have been changes in demand for particular types of facilities and activities. Interest in golf, for example, has grown in the last decade. However, the development of new courses in the area and elsewhere in eastern Newfoundland has helped to meet these new demands.

While the cumulative effects of the three offshore projects will be a long-term increase in population in the area, there is no reason to expect that the mix of public and private suppliers of recreational facilities and services cannot continue to meet any growing or changing demands or that any growth in demand will have an adverse effect.

Isthmus of Avalon Area

The use of local area recreational facilities by Bull Arm workers during the construction project was regarded as beneficial because it did not over-extend the facilities or reduce their availability to local residents, but generated revenue. The SEIS for the smaller Terra Nova project (Petro-Canada 1995) forecast that it would have even fewer such effects, and this has proven to be the case thus far. The same is likely to be so given any White Rose activity and no cumulative effects from other projects are anticipated.

Marystown Area

Offshore-related activities have created little, if any, new demand on recreational facilities in the area. Any White Rose activity is not expected to have different consequences and no cumulative effects are expected.

5.6.3 Integrated Residual Socio-Economic Effects

The types of potential effects by Project phase, the types of mitigation or action that is appropriate, and the evaluation of potential outcomes against the criteria discussed in Chapter 2 are summarized in Table 5.6-2.

Table 5.6–2 Valued Environmental Component: Community Social Infrastructure - Recreation

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction							
Fabrication of offshore components	Increased use of facilities/deman d for services (P/A)	Monitoring/ action by service providers	1	2	1/3	R	2
Installation of offshore components	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations							
Offshore production/ support/service	Increased use of facilities/deman d for services (P/A)	Monitoring/ action by service providers	1	2	3/ 3	R	2
Decommissioning							
Offshore decommissioning / support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Past/Present/Future Projects							
Construction							
Operations	Increased use of facilities/deman d for services (P/A)	Monitoring/ action by service providers	1	2	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
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Frequency:
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Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

The Project will result in some in-migration and some increased demand for access to recreation facilities and programs, primarily during the operations phase. These effects will be mainly experienced in the St. John's area. The magnitude of these effects is expected to be small and existing facilities and programs are expected to be able to cope with any increases. Indeed, for some programs additional involvement may be positive, in terms of program viability and participant enjoyment.

In the past, municipal authorities have coped with larger population increases than have been experienced in the last few years or are anticipated in the near future. Even with the cumulative effects of population growth associated with the direct and indirect employment in three major offshore oil developments, the effects on recreation are not expected to be significant. These conclusions are summarized in Table 5.6-3, based on the criteria outlined in Chapter 2.

No formal Project monitoring is recommended. The authorities responsible for recreation facilities and programs have in place mechanisms to assess and forecast demand for services, and can be expected to respond accordingly.

Table 5.6–3 Residual Socio-economic Effects Summary Matrix

Valued Environmental Component: Recreation				
Phase	Residual Environmental Effects Rating, Including Cumulative Socio-Economic Effects[1]	Level of Confidence	Likelihood	
			Probability of Occurrence	Scientific Certainty
Construction	N/A	N/A	N/A	N/A
Operations	P/NS	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	N/A	N/A	N/A	N/A
Project Overall	P/NS	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable
[1] As determined in consideration of established residual socio-economic effects rating criteria

6 COMMUNITY PHYSICAL INFRASTRUCTURE

6.1 INTRODUCTION

Community infrastructure is valued by local residents, business and industry insofar as its quantity and quality contribute to functioning of the local economy and society and hence, the overall standard and quality of life. This chapter addresses the potential effects of the Project on community physical infrastructure and focuses on housing, industrial and commercial land, warehousing and office space, ports, and airports.

The Project will generate jobs and business activity that, in turn, will increase demands on local infrastructure. As with community services, the implications of these changes are largely a function of the existing supply-demand situation for particular infrastructure at particular locations. If the supply cannot meet current demands, in terms of the availability or quality of that infrastructure which has come to be expected, any incremental effect attributable to the Project will exacerbate the situation. Alternatively, if there is unused or underused capacity, and the incremental change resulting from the Project does not exceed that capacity, the Project will have no significant effect.

Component fabrication and offshore installation employment is relatively short-term and the potential effects on services and infrastructure are expected to be similar to those experienced with the Terra Nova project. Activity levels for Terra Nova have been substantially lower than those for Hibernia, the effects of which proved to be unproblematic.

Offshore operations will result in long-term employment similar in type and level to those expected for Terra Nova, but less than those experienced at the outset by the Hibernia project. Once again, there is no evidence that the latter project has had any adverse effects on community infrastructure. Whether cumulatively these and other projects and activities have had any important effects is examined for each infrastructure component in this section.

For each infrastructure component, this section describes and analyzes the:

- existing socio-economic environment, including:
  - the particular environmental assessment boundaries relevant to the infrastructure component discussed; and
  - existing conditions with respect to each of these infrastructure components.

- socio-economic effects assessment, including:
  - an overview of project-environment interactions;
  - a discussion of socio-economic effects, including cumulative effects; and
  - a summary of socio-economic management initiatives to address potential effects.
- integrated residual socio-economic effects, including:
  - a summary of residual socio-economic effects significance by project phase; and
  - a discussion of monitoring and follow-up initiatives.

6.2 HOUSING

6.2.1 Existing Socio-Economic Environment

6.2.1.1 Assessment Boundaries

The study area boundaries for this discussion of housing conform to those described in Chapter 2. Information on housing is drawn from the Census (Statistics Canada 1991; 1996) and from data compiled by the Canada Mortgage and Housing Corporation (CMHC) and the Newfoundland and Labrador Housing Corporation (NLHC). While detailed data are available for the St. John's area, fewer are available for smaller urban areas, including Clarenville and Marystown. Data for rural areas are even less readily available and are often aggregated on a regional basis. Consequently, the available information for each of the study areas varies by type and level of detail.

6.2.1.2 Existing Conditions

Newfoundland

In 1996, there were 185,500 occupied private dwellings in Newfoundland. This is an increase of 6.3 percent over 1991. The number of dwellings has grown considerably over the past 20 years but the rate of increase has fallen, from 9.7 percent in 1986 to 1991 and 7.2 percent in 1981 to 1986 (Petro-Canada 1995). In 1996, 77.1 percent of private dwellings were owner-occupied. The average rent for tenant-occupied buildings in 1996 was $497 per month, compared to $447 in 1991 (Statistics Canada 1991; 1996).

Over the past decade, the annual number of housing starts has generally declined. In 1990, it was 3,245; by 1999, it was 1,371 (CMHC 2000a). The majority of units constructed were single detached, though periodically, the number of row and apartment units has increased to meet demand.

Information on the specific effects of the offshore oil industry is limited, however, analysis of the economic impacts of Hibernia operations for 1998 indicated that the total (that is, direct, indirect and induced) effects on the Province's economy in that year included 35 additional housing starts, representing 2.4 percent of the total (HMDC 1999).

St. John's Area

In 1996, there were 60,295 occupied private dwellings in the area, of which 61 percent were located within the City of St. John's (Statistics Canada 1996). This represents an increase of 5,115 units over 1991, but the importance of this increase is complicated by changes in City boundaries.

Much of the growth in the region continues to occur in Conception Bay South and Mount Pearl. For example, between 1991 and 1996, Conception Bay South experienced an increase of 1,011 units, or 19.3 percent. In Mount Pearl, the number of units increased from 7,250 to 8,390, an increase of 15.7 percent (Statistics Canada 1991; 1996).

CMHC monitors housing supply and demand in the St. John's area. Annual housing starts in the area have fluctuated over the last decade, with the general trend being one of decline. In 1990, 1,434 units were started, but in 1999, there were only 807 starts (CMHC 2000a).

In recent years, the housing market, as reflected in number and value of sales, has generally improved (Table 6.2-1). These data, compiled by the St. John's Real Estate Board, are based on inputs from all of the Board's members, including those from other parts of the Avalon and Eastern Newfoundland. However, the largest market to which the data refer is the St. John's CMA, the study area for this report.

Table 6.2–1 Housing Market Data, St. John's Real Estate Board Members

Year	Units Sold	Average Price ($)	Annual Increase (%)
1991	1,799	91,123	2.5
1992	1,720	91,959	0.9
1993	1,741	92,319	0.4
1994	1,783	92,011	-0.3
1995	1,572	89,655	-2.6
1996	1,915	94,142	5.0
1997	2,080	92,797	-1.4
1998	2,131	92,560	-0,3
1999	2,298	95,606	3.3

Source: St. John's Real Estate Board, Annual MLS Sales 1991-1999

Apartment vacancy rates for the St. John's area have fluctuated widely over the past decade. In 1990, the rate was 1.8 percent. In 1992, it fell to 0.9 percent, only to reach 16.6 percent in 1997 (Petro-Canada 1995; CMHC 2000b). The period of high vacancy rates from 1995 to 1998 coincides with the completion of the Hibernia project and the out-migration of personnel involved in the engineering and design of the project. Since then, vacancy rates have again fallen; in 1999 it was 9.2 percent (CMHC 2000b).

A decline in rates has accompanied these high vacancy rates. While three bedroom units had seen the highest rate increases in the 1987 to 1995 period, renting for an average of $593 per month in 1995, they have shown the largest decrease since, renting for an average of $535 per month in 1999 (CMHC 2000b).

Social housing in the St. John's area is provided by the City of St. John's and NLHC. At the municipal level, the City administers the Urban Living non-profit housing program. Initiated in 1982, there were 424 units available in 2000, a number that has not changed for several years. Two types of housing are provided, low set-rent units (268) and rent-geared-to-income units (156). All of the latter units are currently occupied, while there is an 11 percent vacancy rate in the former (V. Gamberg, pers. comm.).

In addition, NLHC provides two types of social housing in the St. John's area:

- privately-sponsored, publicly-subsidized; and
- public non-profit housing.

As of 2000, there were approximately 4,000 NLHC social housing units in the St. John's area in the same as in 1995. There has been a long-term high demand for social housing in the area. Existing units have 100 percent occupancy rate, and while there is an annual 10 percent turnover, units are occupied immediately as there is a long waiting list. The 1995 decision to cut federal support for social and seniors housing had a substantial negative effect on the supply of low cost housing. At the same time, demand has continued to increase and housing units age (G. Kennedy, pers. comm.).

Isthmus of Avalon Area

The total housing stock in the Isthmus Area increased by 14.2 percent between 1981 and 1991 and 25.9 percent between 1991 and 1996 (Statistics Canada 1991; 1996). Most of the change was in Clarenville-Shoal Harbour and to a lesser degree, in Arnold's Cove.

Growth in the housing stock has been concentrated mainly in the Clarenville-Shoal Harbour area. In the 1991 to 1994 period, activity at Bull Arm generated a considerable increase in housing starts, with between 51 to 63 starts per year in this period. In 1995, the number decreased to only five units. Since then, there are no data to confirm the number of annual starts but local realtors estimate a similarly small number (N. Norcott, pers. com.).

In 1992, CMHC initiated the *Clarenville-Shoal Harbour House Price Survey* to monitor prices of different types of homes in three different areas of the community. This survey has since been discontinued and there are no formal current data on house prices. A local realtor reports that for the past three years, demand has been generally low with the main interest being in properties located between Clarenville and the Bull Arm site. Recently, the general economic improvements in the area, with increased activity at Bull Arm, Whiffen Head and Come By Chance, has seen some increase in demand and prices (N. Norcott, pers. comm.).

As in most areas of the Province, dwellings in the Isthmus area are predominantly owner-occupied. In 1996, the proportion of owner-occupied units varied from nearly 100 percent in Come By Chance to 67 percent in Clarenville.

Average monthly rents in the area vary considerably over time and amongst communities (Table 6.2-2). In 1996, rents in Clarenville-Shoal Harbour were the highest, and showed the greatest increases since 1991.

Table 6.2–2 Average Gross Monthly Rents ($), 1986-1996, Isthmus of Avalon Area

Municipality	1986	1991	1996
Sunnyside	439	379	N/A
Come By Chance	306	537	534
Arnold’s Cove	293	348	440
Clarenville	408	476	590[1]
Shoal Harbour	403	385	

[1] Clarenville-Shoal Harbour are now one amalgamated municipality
Source: Statistics Canada 1986; 1991; 1996.

Since 1986, the NLHC has constructed 22 social housing units in Clarenville. Sixteen of these were built in 1988, six in 1993 (G. Kennedy, pers. comm.).

Marystown Area

The Marystown area housing market is affected by the seasonal and annual fluctuations in employment by the main employers in the area, the Friede Goldman Newfoundland Shipyard and the fish plant. Increased activity at one or both contributes to greater housing market activity, while layoffs have negative repercussions for the area's housing market.

In 1996, there were 3,895 occupied private dwellings in the area, a 6.6 percent increase since 1991 (Statistics Canada 1991; 1996). Growth in Marystown itself was the main contributor to this increase. As was the case with the Isthmus area, published housing start and price information are not available for individual communities. However, the main realtor for the area reports that the housing market has been slow given layoffs at the shipyard, with considerably more units for sale, particularly in Marystown and Burin, than the previous year (P. Dober, pers. comm.). During the public consultation process, participants from the Marystown area commented on the issue of current capacity, noting that out-migration had resulted in a large number of empty houses and the ready availability of basement apartments.

As elsewhere in the Province, most houses in the area are owner-occupied. The proportion varies among communities, ranging from 85 percent in Winterland, to 71 percent in Marystown (Statistics Canada 1996).

Average gross rents in the area are highly and variable both over time and amongst communities (Table 6.2-3). Rents remain highest in Lewin's Cove, Marystown rent levels have increased significantly since 1991, but otherwise, data gaps do not allow any general patterns to be determined.

Table 6.2–3 Average Gross Monthly Rents ($), 1986-1996, Marystown Area

Municipality	1986	1991	1996
Fox Cove – Mortier Bay	305	345	N/A
Marystown	394	394	508
Winterland	N/A	N/A	424
Burin	325	381	326
Lewin's Cove	329	615	536
Port au Bras	360	N/A	N/A
Garnish	259	395	337
Frenchman's Cove	N/A	270	N/A

Source: Statistics Canada 1986; 1991;1996.

Since 1986, 34 social housing units have been constructed. Of these, 20 were privately sponsored, and 14 were publicly subsidized. At present a number of the units are vacant and boarded up, but no decision has been made as to whether they will be demolished.

6.2.2 Socio-Economic Effects Assessment

6.2.2.1 Project-Environment Interactions

The potential interactions between the Project and the housing market in each of the regional study areas are indicated in Table 6.2-4. There is the potential for increased demands for housing during construction activities and during the operations phase. Construction activity effects could occur in any of the study areas, but effects from operations are only expected to be experienced in the St. John's area. Some cumulative effects may also occur here associated with multiple field development, the growth of the offshore service sector and economic growth generally.

Table 6.2–4 Project-Environmental Effects Interaction Matrix Community Physical Infrastructure: Housing

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication			X		X		X	
Field Development/Installation			X		X		X	
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events								
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

6.2.2.2 Socio-Economic Effects

St. John's Area

Data collected by HMDC and the main project contractors indicated that the Hibernia project had a small effect on the St. John's area housing market (Storey et al. 1996). Most of this was related to leased accommodations. Generally speaking, Hibernia personnel helped to absorb some of the higher priced houses and condominium units on the market. As was indicated in Section 6.2.1, with the completion of the Hibernia project, a number of units were freed up and vacancy rates for rental accommodation were high from 1995 to 1998. The situation has since changed with vacancy rates lower, particularly for middle to upper quality accommodations.

The Hibernia project did not require any specific provisions for more units or building lots in the area during the construction phase. During operations, employment initially reached approximately 800 and has since decreased slightly. However, as was noted above, macroeconomic analysis suggests that Hibernia operations in 1998 generated only 35 additional housing starts Province-wide (HMDC 1999). On-shore managerial, administrative and support personnel need to live within easy access of their workplace, and most are believed to live within the St. John's area. Offshore personnel, on the other hand, need not live in the area, though many do, and many of those employed by the company already lived within the area and did not need to purchase or rent accommodation. The net result is that the area housing market was able to meet the needs of Hibernia employees without difficulty. Coming several years after when the market has absorbed the initial Hibernia demand, the somewhat smaller demands of the Terra Nova project to date (over 400 personnel), or in the future (approximately 400 during production when drilling activity is at peak), are not expected to have a critical effect on the St. John's area housing market.

White Rose requirements are anticipated to be comparable to those for Terra Nova, and demands for housing will occur subsequent to those for that project. The housing market will, therefore, have time to adjust. Any Project-specific direct effects are likely to be small and short-term. They will be beneficial from the perspective of home-builders and suppliers, home sellers and municipal tax authorities.

Cumulatively, the three offshore projects, an expanding offshore supply and service sector, and growth related to other economic activity generally, will increase the demand for housing. As can be seen from Table 6.2-1, the number of units sold and average prices have increased over the last decade. Such growth brings economic benefits but it may have negative consequences for some. While the housing market is generally segmented according to price, the take-up of lower value properties, particularly in the downtown core, and their renovation may have indirect or inflationary effects and place a burden on those on low incomes who find higher prices for accommodations problematic.

Monitoring of demand for financial support for housing is part of the mandate of the Provincial Department of Human Resources and Employment. In the past, they have responded by increasing financial support when rents have increased substantially. Support of those in need, through the provision of social housing, has long been a mitigative strategy, but one that has been primarily dependent on federal funding. Any changes in such funding are typically related to national programs and policies and are unlikely to be forthcoming because of purely local changes in demand.

Isthmus of Avalon Area

Concerns about the ability of the Isthmus area communities to accommodate Hibernia construction workers were largely resolved through the provision of onsite workcamp accommodations (see Table 2.2-1). Some of the workforce did occupy housing in the area; as of March 1995, 114 units (mostly in Clarenville and Shoal Harbour) were occupied by project staff (Petro-Canada 1995). Many of these units were leased. Based on CHMC House Price Surveys and resident surveys, it has been concluded that Hibernia-related demand had little effect on overall demand or house prices, and that any such increases as were experienced were short-term (Jones 1998).

Terra Nova construction activity at Bull Arm has been of a much smaller scale. Workers have either commuted from their homes or found local accommodations. The project has, consequently, had little or no effect on the local housing market.

White Rose construction activity will be of similar type as Terra Nova, and may lead to activity levels similar to those seen in the area in the past. At the White Rose public consultation sessions, local area residents indicated that they would prefer to see workers housed within the community rather than at a camp, as was the case with Hibernia.

The rationale for a camp for Hibernia was in part driven by community concerns that demands for worker accommodations would far exceed the local capacity to meet them. The experience with offshore North Sea and other construction projects indicated that this happened, rents skyrocketed, sub-standard accommodation was offered and used, and conflict between incomers and locals was fuelled by the inadequacy of both housing and other local services. A camp was seen as away to avoid these potential negative outcomes and recognized as such by the Hibernia Environmental Assessment Panel (HEAP 1985).

In retrospect, this proved an effective means of minimizing community disruption, particularly given that the workforce proved to be more than twice as large as originally forecast (Storey et al. 1996; Jones 1998). At the same time, the camp approach meant that a number of community benefits were foregone. Depending on the level of activity at the site should it be used for White Rose development, there may be ways of achieving greater local benefits while avoiding any potential negative consequences. The strategy adopted will largely be a function of the level of activity at Bull Arm which is at present unknown.

To ensure that Husky Oil meets its benefits commitments and addresses local concerns about potential adverse community effects, Husky Oil will work with community representatives regarding any workforce effects, including any decisions regarding the accommodation of workers at Bull Arm.

Given the sequencing of future offshore projects, no cumulative effects are anticipated.

Marystown Area

The Hibernia project raised concerns about the increases in demand for housing in the Marystown area. In 1994, for example, an upswing in activity at the shipyard and at the Fishery Products International (FPI) fish plant had a large effect on rental costs. The main local realtor reported that during that year (1994), monthly rents for two- and three-bedroom bungalows reached $600 and $1,000, respectively (P. Dober, pers. comm.). With reduced activity in 1995, rents fell to approximately $450 and $525, respectively (Petro-Canada 1995).

Terra Nova has had little effect on Marystown and participants in the public consultation process for White Rose drew attention to the fact that there is currently a large excess of infrastructure capacity, including housing. Under the present circumstances, should fabrication and construction contracts for White Rose be awarded to the shipyard, this will have positive rather than any significant adverse effects on housing in the area.

As in the case of the Isthmus area, the level of activity at the shipyard will influence the demand for housing. There is a greater supply of rental accommodation in the Marystown area and considerable experience with fluctuating demand for it with changing activity levels at the yard. Nonetheless, as is the case for the Isthmus area, when potential activity levels are known, Husky Oil will consult with community representatives regarding workforce effects in the area. No cumulative effects are anticipated.

6.2.3 Integrated Residual Socio-Economic Effects

The types of potential effects by Project phase, the types of mitigation or other action appropriate, and potential outcomes according to the criteria discussed in Chapter 2 are summarized in Table 6.2-5. No significant effects on housing are expected. The market is believed to be capable of responding to demand as it has in the past to much greater and less anticipated changes. The effects of increases in demand will, in an overall sense, have positive economic effects.

Table 6.2–5 Valued Environmental Component: Community Physical Infrastructure - Housing

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction							
Fabrication of offshore components	Increased demands for housing (P/A)	Monitoring/ action by responsible authorities	1	2	1/ 3	R	2
Installation of offshore components	Increased demands for housing (P/A)	Monitoring/ action by responsible authorities	1	2	1/3	R	2
Operations							
Offshore production/support/ service	Increased demands for housing (P/A)	Monitoring/ action by responsible authorities	1	2	3/ 2	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support			N/A	N/A	N/A	N/A	N/A
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased demands for housing (P/A)	Monitoring/ action by responsible authorities	1	2	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

Not all individuals will benefit from economic growth associated with the Project. Those on low incomes may find that the cumulative effects of economic growth in the City of St. John's in particular will adversely affect them if rental accommodation costs increase. This is primarily an indirect effect over which the proponent has little influence in terms of mitigative strategies. Overall, Project residual effects are considered to be primarily positive and not significantly adverse. These conclusions are summarized in Table 6.2-6.

Table 6.2–6 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Housing				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects**[1]	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	P/NS	3	3	3
Operations	P/NS	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	N/A	N/A	N/A	N/A
Project Overall	P/NS	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[1] As determined in consideration of established residual socio-economic effects rating criteria

6.3 PORTS AND AIRPORTS

6.3.1 Existing Socio-Economic Environment

6.3.1.1 Assessment Boundaries

The focus of the analysis in this section is St. John's because it has the main port and airport in the regional study areas and because these are also the facilities most likely to be used directly for White Rose activity.

6.3.1.2 Existing Conditions

St. John's Harbour is administered by a crown agency, the St. John's Port Authority. There is a total of approximately 5 km of dockface available, 51 percent of which is owned by the Port Authority. This includes the container and roll-on/roll-off (RoRo) terminal, which serves most of the traffic in the harbour. Of the remaining dockage, 32 percent is privately owned and 17 percent directly or indirectly owned by government departments and agencies.

The port has been considerably underused compared with the early 1980s, when offshore drilling and seismic work were underway and the port was used by large numbers of foreign and Canadian trawlers and the CN Marine freight vessel service to Labrador. As a consequence, there has been significant available capacity. In recent years, growth in the offshore industry has resulted in an increase in port activity but there is still significant potential to handle more traffic.

The port serves as a container and RoRo terminal for vessels carrying general freight on regular runs from Halifax and Montreal. Traffic tonnage declined from 403,000 t in 1990 to 340,000 t in 1994. However, in recent years, cargo tonnage has revived and in 1999 passed the one million tons mark (1,187,770 t). This represents an increase of about 20 percent over 1998. Heading the growth was the handling of liquid bulk, including marine diesel, mud oil and potable water. Liquid bulk increased by 38 percent over 1998, while break bulk material, a combination of drill pipe, equipment and general supplies for the offshore, saw an increase of 35 percent. In 1999, vessel entry numbers associated with the offshore industry increased by 74 percent over 1998 (St. John's Port Authority 2000a).

Liquid fuels are imported to serve domestic and industrial needs, marine traffic and the airport. Irving Oil and Esso tankers pump from dockside terminals into storage tanks on the south side of the harbour. Tankage formerly used by Ultramar is now leased to Petro-Canada to service the offshore industry. Fishing vessels use the small boat basin on the south side of the harbour near Fort Amherst and dockface space at the northwestern end.

The redeveloped A. Harvey wharf, at the northeastern end of the harbour, has been the base for Hibernia, and now Terra Nova, shore-based marine services since 1997. It has also been used by Husky Oil during both exploration and the delineation of the White Rose field. Warehousing and lay-down activities for current offshore activity have been concentrated in the Donovan's Industrial Estate, Mount Pearl. In anticipation of further offshore development, the St. John's Port Authority recently announced a $13 million reconstruction of Pier 17 for a 150,000 square feet (13,935 m^2) multi-use facility to service the oil industry (St. John's Port Authority 2000b).

The St. John's International Airport is the busiest commercial airport in the province. The St. John's International Airport Authority Inc. assumed control in December 1998. The Authority is a not-for-profit corporation that runs the Airport as a commercial business operation.

The Airport is characterized as an "end of the line" airport in the national context, but it does serve as a "hub" for traffic within the Island of Newfoundland, and as a "gateway" to European markets. The main terminal serves scheduled national and international passenger aircraft, most charter flights and air cargo traffic. General aviation activities take place on the east side of the airport, while helicopters, some military and some private aircraft use the multi-purpose Cougar Helicopters Inc. facility, adjacent to the main terminal, on the west side. Universal Helicopters Ltd. has its terminal building and landing area, under the control of the airport control tower, but outside Airport property, on Major's Path.

The volume of commercial passenger traffic in 1988 was 702,264 persons. By 1995, this had declined by approximately 11 percent. As of 1999, volume had increased to 800,316, but remained below historic peaks (St. John's International Airport 2000). In response to increased passenger demand and anticipated further increases, the Airport Authority is presently undertaking a $48 million redevelopment program, which includes a series of runway improvements and extension and upgrading of the terminal building. The redevelopment is scheduled for completion in 2002. When complete, the airport will be able to accommodate larger aircraft and the terminal building will be three times its present size (W. Butt, pers. com.).

Air cargo has declined from a peak in 1984. Current facilities can handle present traffic volumes, but a site has been set aside to accommodate increased traffic when needed. The general aviation area includes several hangars, with associated office and service buildings. The main operators are Air Atlantic, Canadian Helicopters Ltd., Provincial Airlines Ltd., the provincial government, and the federal government (Coastguard, Customs, Transport Canada, etc.).

6.3.2 Socio-Economic Effects Assessment

6.3.2.1 Project-Environment Interactions

The types of Project-environment interactions that might occur are indicated in Table 6.3-1. The port will be used if topsides or subsea components are fabricated at the NEWDOCK shipyard. Husky Oil has indicated that it will use an existing marine supply base to support offshore production. The harbour and airport will also be used as necessary in the event of accidents or other unplanned events.

Table 6.3–1 Project-Environmental Effects Interaction Matrix Community Physical Infrastructure: Port and Airport

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X					
Subsea Units Fabrication			X					
Field Development/Installation			X					
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events			X					
Past/Present/Future Projects								
Construction								
Operations			X					

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

6.3.2.2 Socio-Economic Effects

As noted, three operators are currently using the A. Harvey wharf and its capacity has been, and is projected to be, sufficient to adequately support field development and ongoing operations. Other potential supply base capability exists within the harbour, and there is further potential in Bay Bulls.

St. John's has efficient services, such as trucking, pilotage, stevedoring, water supply, ship chandlering, repair and servicing shops, waste disposal and vessel traffic monitoring. Use of the port by Husky Oil for the Project will benefit the Port Authority and potential asset sharing opportunities offer economies for Husky Oil and the other operators. At the same time, increased activity is not expected to adversely affect other port users. The limited volume of other traffic in the harbour suggests that any cumulative effects of multiple field development will not be problematic.

In 1995, Cougar Helicopters Inc. was awarded a five-year contract to support Hibernia development and production activities and constructed a purpose-built facility on the west side of the airport to do this. The facility has 1,020 m^2 of hangar space and 650 m^2 for ancillary uses, and serves three Super Puma helicopters (Petro-Canada 1995). Air (helicopter) support for the White Rose oilfield development will be determined through a competitive bidding process.

As noted, airport traffic is increasing, but is below historic peaks. Notwithstanding this, new facilities and the current expansion program will increase capacity and allow considerably more traffic to be accommodated without difficulty and without adversely affecting existing users. Any cumulative effects will generate more revenue for the Airport Authority.

Increased air traffic will not affect highway access to the Airport. Torbay Road is now a four-lane urban arterial running downtown, Portugal Cove Road is four lanes as far as New Cove Road, and the Outer Ring Road is complete as far east as Portugal Cove Road and should be complete as far as Logy Bay Road by 2003.

6.3.3 Integrated Residual Socio-Economic Effects

The types of effects anticipated by project phase, any mitigative measures necessary, and potential outcomes against the significance criteria discussed in Section 2 are summarized in Table 6.3-2.

Effects of the Project on both the Port of St. John's and St. John's International Airport are expected to be significant and positive. Their greater use, from Project-related activities and cumulatively from other activities, will generate increased revenues for both administrative authorities, but should have no negative effects on other users.

Table 6.3–2 Valued Environmental Component: Community Physical Infrastructure – Port and Airport

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction:							
Fabrication of offshore components	Increased use of Port and Airport (P)	Monitoring/ action by service providers	1	1	1/ 3	R	2
Installation of offshore components	Increased use of Port and Airport (P)	Monitoring/ action by service providers	1	1	1/ 3	R	2
Operations							
Offshore production/ support/service	Increased use of Port and Airport (P)	Monitoring/ action by service providers	1	1	3/3	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A 3	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support	Increased use of Port and Airport (P)	Monitoring/ action by service providers	1	1	3/ 3	R	2
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased use of Port and Airport (P)	Monitoring/ action by service providers	1	1	3/ 3	R	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

No mitigative measures are considered necessary. The port and airport authorities monitor activities on an ongoing basis and can be expected to respond to any customer needs as they emerge. The residual effects for these infrastructure elements are summarized in Table 6.3-3.

Table 6.3–3 Residual Socio-Economic Effects Summary Matrix

Valued Environmental Component: Port and Airport				
Phase	Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects[1]	Level of Confidence	Likelihood	
			Probability of Occurrence	Scientific Certainty
Construction	P	3	3	3
Operations	P	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	P	3	3	3
Project Overall	P	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

N/A = Not Applicable

[1] As determined in consideration of established residual socio-economic effects rating criteria

6.4 INDUSTRIAL AND COMMERCIAL LAND, WAREHOUSING AND OFFICE SPACE

6.4.1 Existing Socio-Economic Environment

6.4.1.1 Assessment Boundaries

The demand for industrial land arising from the Project will depend on the nature of the work that is carried out in Newfoundland. Part of Husky Oil's commitments are to attempt to maximize business and employment benefits to the Province within a competitive framework and, given the technical similarity of the Project to Terra Nova, the assumption made is that the same types, if not the same levels, of demands for industrial and commercial land, warehousing and office space will be generated by White Rose as Terra Nova.

The requirements for industrial land will, therefore, potentially include fabrication yards such as those at Bull Arm, Marystown and St. John's, and light industrial land such as is found in industrial estates in Mount Pearl, Paradise and St. John's.

St. John's and Mount Pearl are the only communities within the study areas with significant commercial warehouse and office space. In this analysis, therefore, primary attention is given to those communities within the defined study areas that offer these types of infrastructure. A more detailed description and discussion of industrial facilities and capabilities will be provided in the Canada-Newfoundland Benefits Plan.

6.4.1.2 Existing Conditions

St. John's Area

The dockyard in St. John's (NEWDOCK) is operated by St. John's Dockyard Ltd. The yard covers approximately 7.5 ha (18.5 acres) at the western end of the Port of St. John's and includes a graving dock, a marine elevator, transfer and repair berths, mobile cranes, fabrication shops, warehousing and laydown areas. Approximately 2 ha (5 acres) of laydown area are available. NEWDOCK's capabilities include provision of marine services (ship repair, etc.) and offshore services (component fabrication, testing, etc.) (St. John's Dockyard Limited 2000).

Large areas of industrial and commercial land have been earmarked for industrial uses in the St. John's area. In the 1970s, industrial land was developed and absorbed into the market at an average rate of approximately 8 ha per annum. Demand peaked in 1980 at 37 ha. Since then, until the mid-1990s, demand declined. For example, from 1986 to 1990, average annual demand in Donovan's Industrial Park was 9.5 ha, but from 1991 to 1994, this fell to 0.3 ha. Since 1994, demand has once again increased, averaging 12 ha/a until 1999, when 28 ha were sold (D. Whalen, pers. comm.).

Land availability at industrial parks in the St. John's area is summarized in Table 6.4-1. All sites could be used for warehousing or machine shops, depending on zoning; some areas are best suited to lay-down areas for open storage.

Highway access from these industrial lands to other key infrastructure elements such as the Port of St. John's and the St. John's Airport is generally good, and east-west access has been improved with the development of the Outer Ring Road. Highway improvements have facilitated access for port traffic coming from the west, but access to the port for large vehicles coming from the east is still constrained by grades.

Table 6.4–1 Major Industrial Parks, St. John's Area

Name	Developed (ha)	Vacant Serviced (ha)	Vacant Unserviced (ha)	Total (ha)
Donovan's Industrial Park	175.4	16.0	38.5	230.0
Donovan's Industrial Estates	22.1	1.6	0.0	23.7
St. Anne's	10.9	1.2	0.0	12.1
Octagon Pond	0.0	0.0	40.5	40.5
Harvey's Industrial Estate	0.0	8.1	16.2	24.3
Beclin Industrial Estate	9.0	0.0	13.3	22.3
White Hills Industrial Estate[1]	n/a	n/a	n/a	24.0
O'Leary Avenue Industrial Estate[1]	87.0	0.0	0.0	87.0

[1] 1996 data, current data not available

Sources: City of Mount Pearl, Donovan's Industrial Estates, Town of Paradise, A. Harvey and Co., Beclin Ltd., City of St. John's, Petro-Canada 1995

St. John's and Mount Pearl are the only communities in the study area with substantial amounts of commercial warehouse and industrial space. Surveys carried out by the cities of St. John's and Mount Pearl in 1994 and 1995 have not been updated and more recent data compiled by Royal LePage are not directly comparable because of methodological differences. These most recent data for the Greater St. John's area (St. John's, Mount Pearl and Paradise) are summarized in Table 6.4-2. It should be noted that owner-occupied buildings and buildings of less than 929 m^2 (10,000 square feet) are not included in the survey.

Table 6.4–2 Industrial Space Availability, Greater St. John's Region, First Quarter 2000

Location	Gross Leasable Area (sq. m)	Vacancy (%)
Mount Pearl/Paradise	102,805	11.05
St. John's North[1]	66,335	8.3
St. John's Downtown/Central[2]	18,041	41.74
St. John's West[3]	11,849	31.75
St. John's East[4]	23,493	37.7

[1] O'Leary Ave. area

[2] Water Street, Blackmarsh Road areas

[3] Pearl Place, James Lane

[4] Stavanger Drive, Major's Path, Vanguard Court, Logy Bay Road areas

Source: Royal LePage 2000a

In general terms, the first quarter 2000 survey reflects a strong and active industrial market. While vacancy rates have risen recently, this can be attributed to the addition of six new buildings in the region since the previous quarter. The high vacancy rates in the St. John's Downtown/Central, West and East areas reflect the age and size of the properties available. Those in Mount Pearl/Paradise and St. John's North are much newer and better able to meet current user needs. The development of a 1,290 m^2 oil service centre in St. Anne's Industrial Park in the summer of 2000 and a new 26-ha industrial park in Paradise will add further capacity to the region (Royal LePage 2000a).

Office space for administrative and development- and operations-phase activities (other than that for industrial, warehousing or similar support activities), is mainly found in St. John's. As was the case with the industrial space survey, the only current information on office space is that produced by Royal LePage (Royal LePage 2000b). Available space by region within the City of St. John's is shown in Table 6.4-3. It should be noted that the survey does not include owner-occupied buildings or those less than 1,860 m^2 (20,000 square feet)

Table 6.4–3 Office Space Availability, St. John's, Newfoundland, First Quarter 2000

Location	Gross Leasable Area (sq.m)	Vacancy (%)
Downtown[1]	129,493	20.9
Central[2]	29,038	11.5
North[3]	31,860	7.65
East and West[4]	32,264	14.0

[1] Water Street, New Gower Street, etc.

[2] Freshwater Road, Harvey Road, Bonaventure Ave, etc.

[3] O'Leary Avenue, Kenmount Road, etc.

[4] Newfoundland Drive, Torbay Road, Elizabeth Avenue, etc.

Source: Royal LePage 2000b

Within the Area, the greatest demand is for Class A space, all of which is in the Downtown area. Forty-three percent of the downtown space is considered Class A but within that segment, there is only a 2.9 percent vacancy rate. Activity in the Downtown area is generally high as investors seem to be migrating to the core, and purchasing buildings for office, retail and residential condominium conversions (Royal LePage 2000b). Current and proposed developments related to the tourism sector include the expansion to the Holiday Inn (Royal LePage 2000b).

Isthmus of Avalon Area

The Bull Arm site represents the most significant industrial lands in the Isthmus Area that are relevant to the offshore industry. The site, now owned by the provincial government, comprises three main areas: the drydock site, the fabrication and assembly yard, and the construction camp/administration area.

The camp was designed as a largely self-contained facility. During the Hibernia construction, the workforce peaked at almost 5,800, of which 3,400 were resident on site. Since then, the camp has been closed and most of the accommodation units removed. The fabrication and assembly yard is currently in operation in support of the Terra Nova project.

Other industrial and commercial lands in the area are concentrated in Clarenville and Arnold's Cove. Since 1978, NLHC has developed and marketed three phases of general-commercial, light industrial land areas in Clarenville and a total of 22.8 ha has been developed. Land in the first two phases is fully occupied. Phase III, comprising 7.7 ha was made available in 1995 of which 1.9 ha is vacant. NLHC also developed a further 10.1 ha for institutional, public works and retail uses, which is occupied by the James Cross Memorial Hospital and the Random Mall.

In Arnold's Cove, NLHC developed 4.7 ha of serviced land. One hectare has been sold, and another 8 ha are planned and ready for development as the need arises (W. Slade, pers. comm.).

Marystown Area

Friede Goldman Newfoundland Limited owns and operates the Marystown shipyard and the Cow Head Offshore Fabrication Facility. The shipyard has a syncrolift platform dock with hoists accompanied by a side transfer system to accommodate multiple vessels at one time. The facility also has an in-house fabrication area of 9,358 m^2, with 300 m of water frontage. The yard handles boat construction and repair, refitting, conversion and maintenance for fishing fleet and offshore-related vessels, as well as rig component construction and outfitting.

The Cow Head facility, completed in the early 1990s, has facilities to handle offshore construction, including fabrication of components and rig repair and modification capabilities. The facility covers 81,000 m^2 and includes 14,000 m^2 of covered-in fabrication area (Friede Goldman Newfoundland Limited 2000).

6.4.2 Socio-Economic Effects Assessment

6.4.2.1 Project-Environment Interactions

Potential Project-environment interactions are illustrated in Table 6.4-4. During the construction/ installation phase, depending on where contracts are awarded, there will be a demand for industrial and commercial land, warehousing and office space. During operations, there will mainly be a demand for industrial lay-down space, light industry space, and office and warehouse space. During this phase, the demand will be in the St. John's area. Accidental events are not expected to have any different or additional requirements, but may involve short-term land-uses. Depending on what other activities are ongoing at the time of the construction phase for White Rose, there could be some cumulative demands from various projects for land, office space, etc. During the operations phase, the three offshore projects and any other developments will have a cumulative effect on the St. John's area.

Table 6.4–4 Project-Environmental Effects Interaction Matrix Community Physical Infrastructure: Industrial and Commercial Land, Warehousing and Office Space

	Newfoundland[1]		St. John's Area		Isthmus Area		Marystown Area	
Project Activities and Physical Works	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**	**Dd**	**Di**
Construction and Installation								
Topsides Fabrication/Outfitting			X		X		X	
Subsea Units Fabrication			X		X		X	
Field Development/Installation			X		X		X	
Operations								
Administration			X					
Supply Base/Warehousing			X					
Helicopter Transport			X					
Offshore Production/Marine Support			X					
Tanker Transport								
Decommissioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events								
Past/Present/Future Projects								
Construction								
Operations			X	X				

[1]Newfoundland, excluding the St. John's, Isthmus and Marystown areas

Dd = Direct Demand

Di = Indirect Demand

6.4.2.2 Socio-Economic Effects

St. John's Area

Growth of the offshore industry has resulted in the take-up of industrial land, particularly in Donovan's Industrial Park. Between 1996 and 1999, some 52 new oil-related companies established in the Mount Pearl area alone (HMDC 1999). Such developments are beneficial to the local economy in terms of the direct and indirect employment and income effects that they generate, including taxes to municipal and other authorities.

As indicated in Table 6.4-1, supply of land in the Donovan's and O'Leary Avenue industrial parks is now becoming limited, and additional demands will have to be met through development of new land on existing estates, displacement of existing users, or location elsewhere in the region. This has prompted the City of St. John's and the St. John's Airport Authority, for example, to explore jointly opportunities to develop additional land on the Torbay Road side of the airport. Bounded by Torbay Road, the north side of RCAF Road, the existing hangars on the airport apron and the Ann Jeannette residential trailer park, a total of 86 ha is available and could be added to the existing supply of industrial land in the area (City of St. John's 2000).

The offshore operators, industry suppliers and contractors have and will continue to take up warehouse and office space in the St. John's area. For example, in 1998, HMDC and 14 of its partners or major contractors were using approximately 14,865 m^2 (160,000 square feet) of office, commercial and industrial space in the City of St. John's. These properties contributed to the local economy through their direct and indirect employment and business effects, including the rents paid and the requirements for janitorial, maintenance, office supplies and other such services. This space had a total assessed value of about $13.2 million, generating over $250,000 per annum in municipal tax (HMDC 1999).

Terra Nova and Husky Oil personnel also presently occupy office space in downtown St. John's and will require additional industrial and warehouse space once their projects are in operation. These will benefit the area and should not exceed its capacity or capability to meet demand. During the public consultation process, planners from both St. John's and Mount Pearl indicated that there is sufficient industrial and commercial space of all types to meet demands from White Rose and from any cumulative growth associated with the offshore industry or sectoral activity within the region.

Isthmus of Avalon Area

The Hibernia platform was constructed and assembled at the Bull Arm site. The capacity of the site met the requirements placed upon it by the Terra Nova project and no difference is anticipated were the site to be used for White Rose. The use of the site for Hibernia and Terra Nova has been beneficial to the local as well as provincial economies and any use made of it for the White Rose would continue these benefits. No demand for additional industrial land is expected in Clarenville, Arnold's Cove or other Isthmus area communities.

Marystown Area

The Marystown shipyard and the Cow Head facility are capable of accommodating any demands placed upon them by the White Rose Project. In addition to refits of mobile offshore drilling units (MODUs), the yard has, for example, built two tugs for the oil-transshipment facility at Whiffen Head, and 14 steel bridge support jackets for the Phase II expansion of that facility. The Cow Head facility built topside drilling modules and pipe racks for the Hibernia project. Additional work on the Project or from other activities would be welcomed and generate benefits for the area.

6.4.3 Integrated Residual Socio-Economic Effects

The types of effects anticipated by project phase, any mitigative measures necessary, and potential outcomes against the significance criteria previously identified are summarized in Table 6.4-5.

Potential effects of the Project on industrial and commercial lands, warehousing and office space are considered likely to be positive. The capacity to accommodate most requirements is already in place. Land is available for additional development, should it be required. Increased activity will generate direct and indirect employment and income benefits both from the Project itself and cumulatively with developments in other sectors.

The municipal authorities and other public and private land developers track industrial and commercial occupancy characteristics and respond accordingly. No specific mitigative measures are required at this time and no monitoring beyond what is currently undertaken is considered necessary.

The residual effects with respect to these infrastructure components are summarized in Table 6.4-6. As indicated, the outcomes, including any cumulative effects, are predicted to be positive, with no significant adverse effects.

Table 6.4–5 Valued Environmental Component: Community Physical Infrastructure – Industrial and Commercial Land, Warehousing and Office Space

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Environmental Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction							
Fabrication of offshore components	Increased demands for land, office space, etc. (P/A)	Monitoring/action by responsible authorities/ private sector	1	1	1/3	R	2
Installation of offshore components	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations							
Offshore production/support/service	Increased demands for land, office space, etc. (P/A)	Monitoring/action by responsible authorities/ private sector	1	1	3/3	R	2
Decommissioning							
Offshore decommissioning/ support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Malfunctions/Accidents/Unplanned Events							
Emergency response/support	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Past/Present/Future Projects							
Construction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Operations	Increased demands for land, office space, etc. (P/A)	Monitoring/action by responsible authorities/ private sector	1	1	3/2	I	2

KEY

Magnitude:
1 = Low: within current capacity, standard or threshold
2 = Medium: approaches current capacity, standard or threshold
3 = High: exceeds current capacity, standard or threshold

Geographic Extent:
1 = Individual Community
2 = Regional Study Area
3 = Province

Frequency:
1 = single occurrence
2 = occasional occurrence
3 = continuous

Socio-Economic Context:
1 = Area has no previous experience with offshore development
2 = Area has previous experience with offshore development

Duration:
1 = Construction only
2 = Operations only
3 = Life of Project
4 = Decommissioning only

Reversibility:
R = Reversible
I = Irreversible

N/A =Not Applicable

Table 6.4–6 Residual Socio-economic Effects Summary Matrix

Valued Environmental Component: Industrial and Commercial Land, Warehousing and Office Space				
Phase	**Residual Environmental Effects Rating, Including Cumulative Socio-economic Effects[1]**	**Level of Confidence**	**Likelihood**	
			Probability of Occurrence	**Scientific Certainty**
Construction	P/NS	3	3	3
Operations	P/NS	3	3	3
Decommissioning	N/A	N/A	N/A	N/A
Malfunctions, Accidents, Unplanned Events	N/A	N/A	N/A	N/A
Project Overall	P/NS	3	3	3

Key:

Residual Socio-economic Effects Rating:

S = Significant Adverse Effect
NS = Not-significant Adverse Effect
P = Positive Effect

Probability of Occurrence:
(based on professional judgement)
1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

N/A = Not Applicable

Level of Confidence:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Scientific Certainty:
(based on scientific information, statistical analysis or professional judgement)
1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[1] As determined in consideration of established residual socio-economic effects rating criteria

7 FISHERIES

The fishing industry has undergone significant structural changes in the last decade following the closure of traditional groundfish fisheries and is again highly viable. Among the Goods Industries in Newfoundland and Labrador, fisheries accounted for 35 percent of employment in 1998 and ranked second only to oil production, mining and quarrying in terms of contribution to GDP (contribution from fishing and trapping: $158 million; GDP contribution from oil production, mining and quarrying: $747 million) (Budget 2000).

Given the renewed strength of the fishing industry, issues have been raised about potential losses in catch and income as a result of the proposed White Rose oilfield development. This portion of the SEIS assesses the overall impact of the White Rose project and describes mitigation measures that would reduce any effects on fisheries.

7.1 EXISTING ENVIRONMENT

7.1.1 Assessment Boundaries

7.1.1.1 Socio-Economic Assessment Boundaries

The fisheries assessment focuses on an economic analysis of fish catches (landed value, 1992 to 1998) in the White Rose area, with reference to the greater Grand Banks, and includes expert opinion on the changing nature of fisheries. White Rose, along with Terra Nova and Hibernia, is located on the eastern edge of NAFO division 3L, in NAFO unit area 3Lt (Figure 7.1-1). The Northwest Atlantic is separated into a series of major and minor grids corresponding to NAFO divisions and NAFO unit areas. Although fisheries management and harvesting cross NAFO boundaries, the divisions and unit areas can be used as a common reference point to discuss fisheries. For this assessment, the Grand Banks (and the Flemish Cap) include NAFO divisions 3L, 3M, 3N and 3O (Figure 7.1-2). Only Canadian catches (commercial) are considered. It is assumed that effects on Canadian catches are representative of effects on international catches and any future aboriginal fishery. At present there are no aboriginal, recreational or subsistence fisheries in 3Lt. An aboriginal fishery might develop in the future, but it is highly unlikely that either a recreational or subsistence fishery will develop in this area, more than 300 km offshore.

Effects are assessed with respect to loss of access to fishing grounds, damage to fishing gear or vessels, biophysical effects on fisheries (through effects on fish), and oil spills. Benefits from increased information, communication and emergency response capabilities on the Grand Banks are also considered, as are cumulative effects resulting from White Rose, Terra Nova and Hibernia operations, general marine transportation, seismic testing and exploration drilling.

Figure 7.1-1 White Rose Project Location

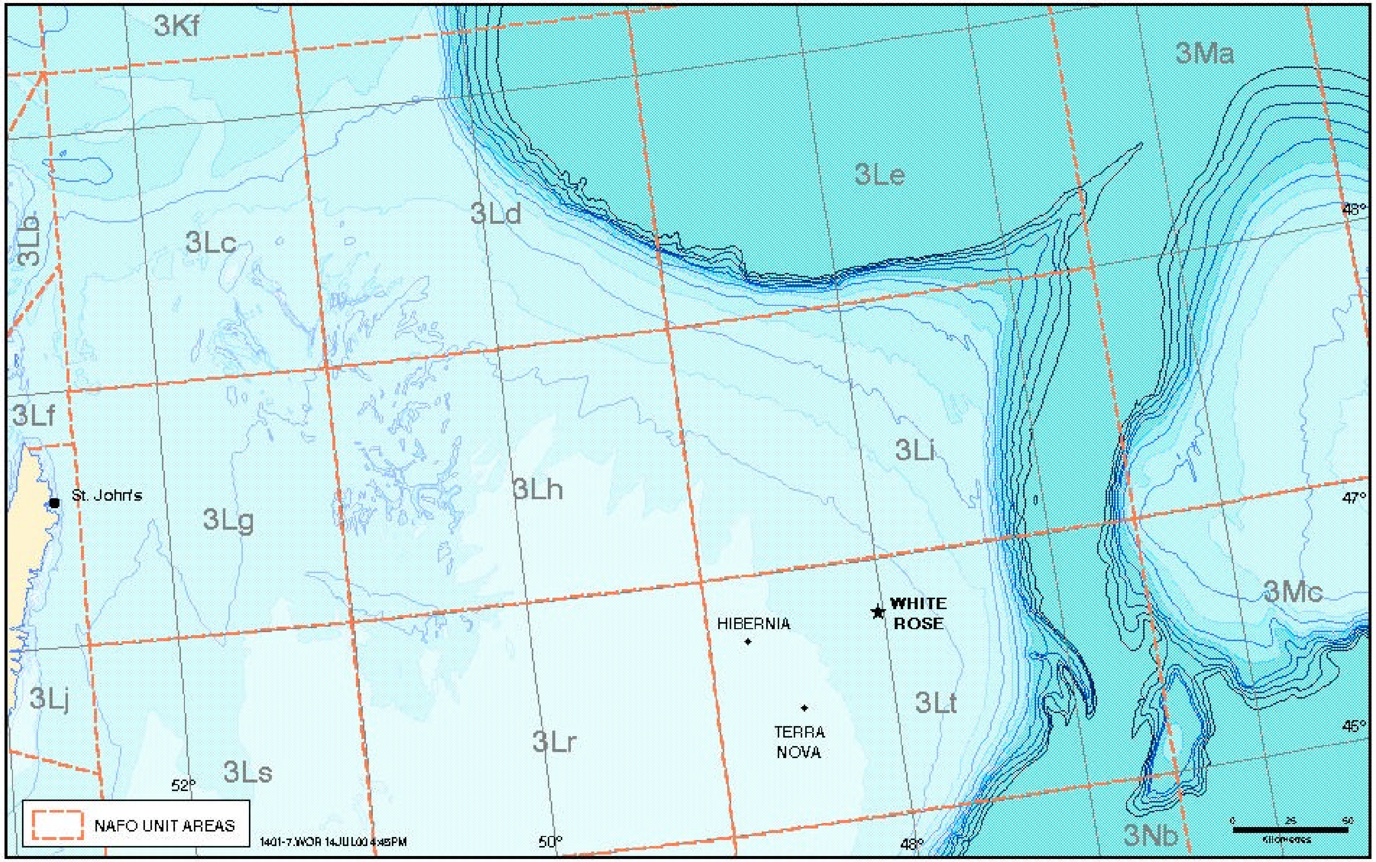
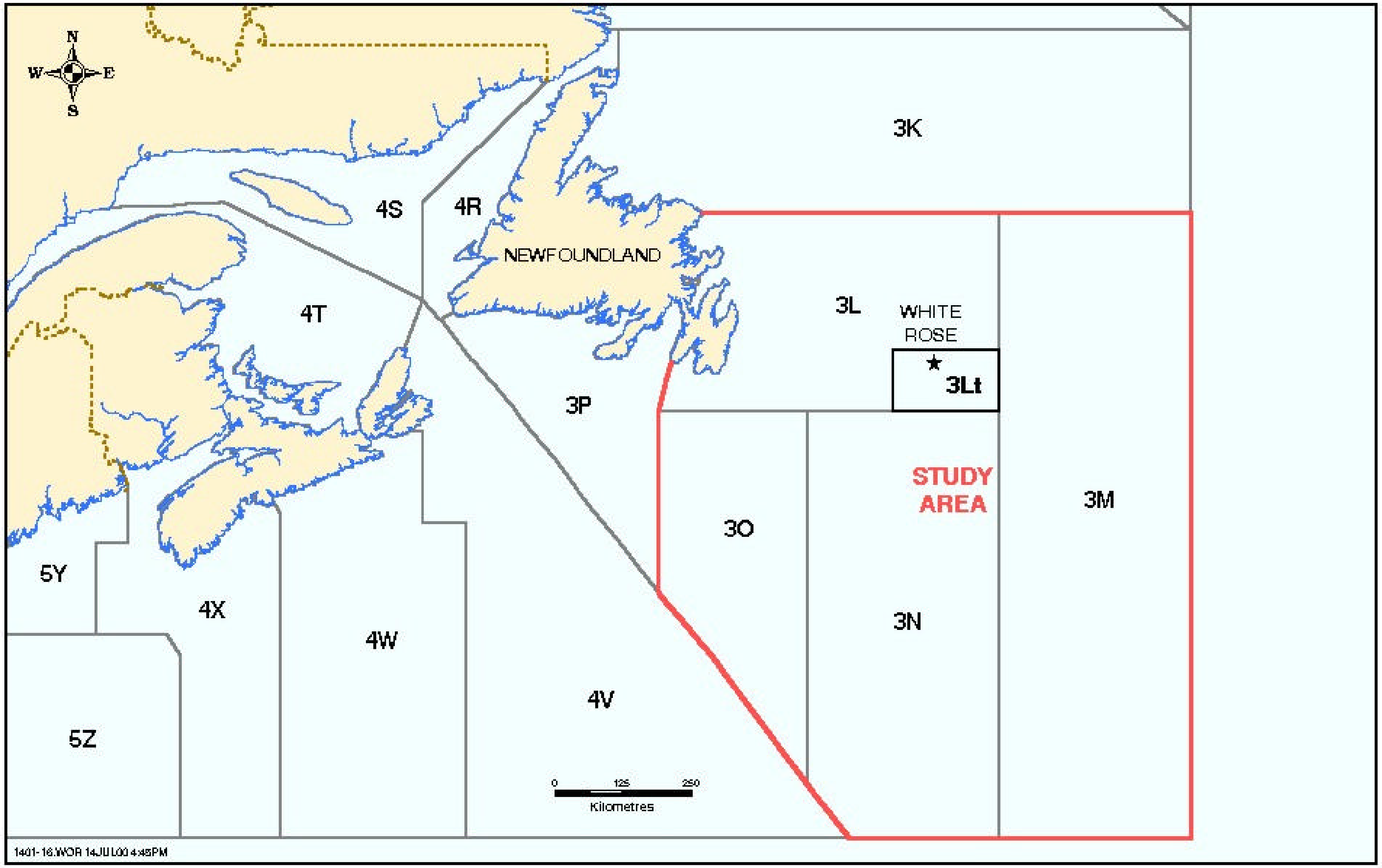


Figure 7.1-2 Study Area



7.1.1.2 Administrative Boundaries

Both NAFO and DFO manage fisheries in the Project area. NAFO assumes primary responsibility for straddling stocks, with advice from DFO. DFO assumes primary responsibility for stocks that do not straddle the 200-mile (322 km) limit or that are sedentary.

7.1.1.3 Technical Boundaries

Constraints on baseline and effects assessment include the changing nature of fisheries on the Grand Banks and the unavailability of catch statistics for 1999. With respect to oil spills and biophysical effects in general, prediction of effect is made more difficult because of the large natural variability in recruitment typically observed in fish populations.

7.1.2 Existing Conditions

7.1.2.1 Information Sources

The main sources of information used in this assessment include:

- fisheries catch statistics data 1992 to 1998 (DFO, Statistical Analysis Division);
- interviews with fishers, scientists and managers;
- research vessel survey data (DFO, Science Branch); and
- DFO Management Plans, Stock Status Reports and Research Documents.

Because important fisheries in each NAFO division are different, data from NAFO divisions 3L, 3M, 3N and 3O are considered separately, except for very general comments. Assessment of industry structure and likely trends in future fisheries draw on a number of sources, identified throughout the text. References are provided in Chapter 9. Catch value and landed weight by species for each NAFO unit area in 3L and neighbouring unit areas in 3M, 3N and 3O are provided in the *Summary Data Tables for Fisheries SEIS* (CHART 2000).

7.1.2.2 The Changing Fisheries: General Overview

The Grand Banks fisheries have undergone substantial changes since the collapse of groundfish stocks. Groundfish (mostly northern cod) accounted for 63 percent of the catch by weight on the Grand Banks in 1987 (Petro-Canada 1995). In 1998, catches of snow crab, capelin, yellowtail flounder and redfish made up the bulk of the catch (81 percent). In 3Lt, the groundfish fishery (northern cod and American plaice) made up 99 percent of the catch by weight in 1987. In 1998, the fishery in this area was dominated by snow crab (98 percent).

Overall, the Grand Banks fishing industry was more lucrative in 1998 ($74 million landed value) than it was 11 years prior (roughly $62 million; Petro-Canada 1995). New fisheries continue to emerge with the opening of a shrimp fishery in NAFO division 3L in 2000 (NAFO Fisheries Commission 2000). Shrimp, seaweed, sea urchins, sea cucumber, whelks, new crab species and seals are currently targeted for increased harvesting or product enhancement under the Canada/Newfoundland Fisheries Diversification Program (Executive Council, Government of Newfoundland 1999).

New fisheries, along with various license buy-back and retirement programs (Table 7.1-1), have led to substantial changes in industry structure. More relevant licensing changes to fisheries around White Rose include a reduction in the number of groundfish licenses and increases in the number of shrimp, crab and scallop licenses. As the fishery moved away from traditional groundfish species in the 1990s, the number of Newfoundland-owned vessels smaller than 65 ft fishing the Grand Banks greatly increased and the number of vessels greater than 125 ft decreased from approximately 58 in 1992 to 14 in 1998 (detailed in following sections).

Table 7.1–1 Number of Licenses, Newfoundland Region 1992 and 1999

Species	1992 Total	1999 Total
Groundfish	9,506	5,359
Lobster	4,425	3,253
Capelin FG	3,112	1,993
Herring FG	3,116	2,412
Scallop	811	975
Mackerel	1,055	1,913
Seals	6,321	10,050
Squid	1,694	3,016
Crab	751	761
Shrimp	58	410

Source: DFO Licensing Division 1999

7.1.2.3 Current Grand Banks Fisheries

Catches and Stock Status

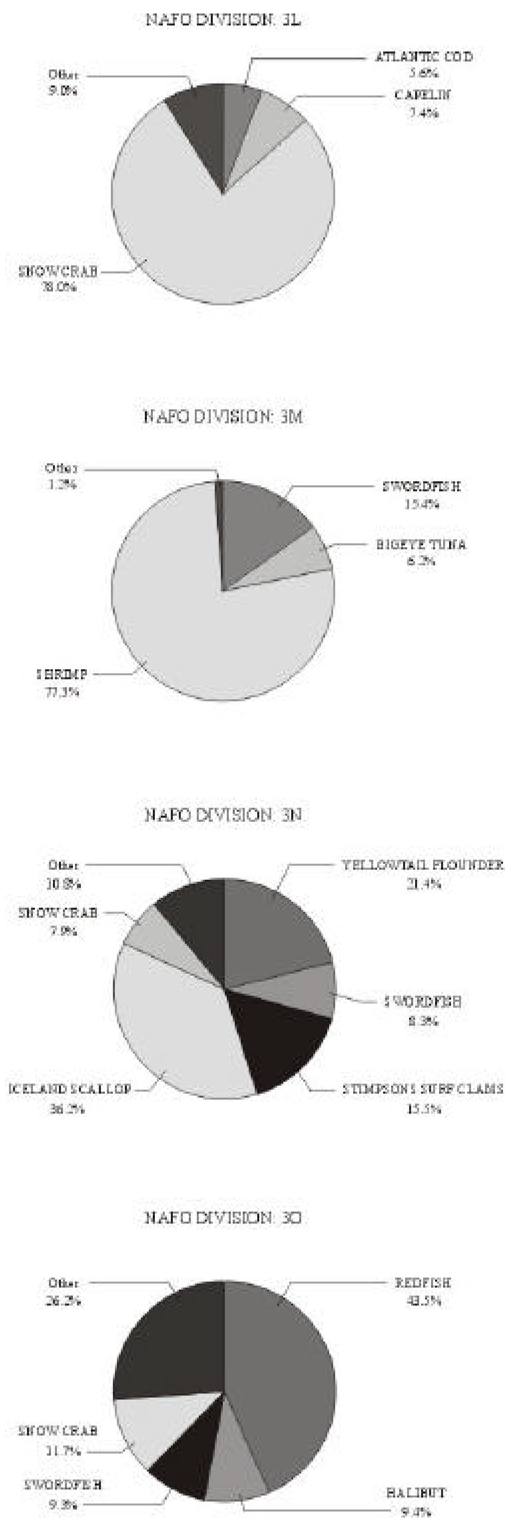
Grand Banks fisheries differ across NAFO divisions. The highest cash landings in 1998 were from snow crab in 3L, northern shrimp in 3M, Iceland scallop in 3N and redfish in 3O. Secondary offshore catches included swordfish in 3MNO, bigeye tuna in 3M, yellowtail flounder and Stimpsons surf clam in 3N and Atlantic halibut in 3O. By weight, the thorny skate fishery was also of some importance in 3O (Figures 7.1-3a and 7.1-4a). The following summarizes each of these fisheries by NAFO division.

Cash landings for 3L crab peaked in 1994 when crab prices reached a maximum. Catch by weight increased steadily from 1992 to 1998 (Figures 7.1-3b and 7.1-4b), but is expected to decrease in 2000. A 45 percent decrease in crab abundance was noted in 1999 and a decrease in recruitment is projected for 2000 (DFO Science Stock Status Report C2-01 2000). Total allowable catch (TAC) for the upcoming fishing year has been reduced by 20 percent in 3L (35 percent TAC reductions are in place further north). Exploratory crab fisheries have also been reduced, with most substantial reductions occurring in the offshore (DFO Integrated Crab Management Plan 1999-2000; R. Coombs, pers. comm.). In contrast, a new shrimp fishery is opening in 2000 in 3L, with a TAC allocation to Canada of 5,000 t (NAFO Fisheries Commission Reports 2000). The shrimp fishery in 3L may become more important over the coming years (see below).

Catch per unit effort (CPUE) for shrimp in 3M has remained relatively stable since 1994 (Skuladottir et al. 1999). However, due to a decrease in fishing effort, Canadian catches have declined slightly (Figures 7.1-3b and 7.1-4b). There are strong indications that shrimp stocks on the Grand Banks and on the Flemish Cap are healthy (NAFO Fisheries Commission 2000; NAFO Scientific Council 1999a; DFO Science Stock Status Report C2-05 2000; Garabana 1999; Angel, 1999; Nicolajsen 1999). Swordfish is an important catch in 3M (and less so in 3NO); bigeye tuna is a much smaller proportion of the catch (Figures 7.1-3b and 7.1-4b). The 1999 stock assessment for swordfish reports that numbers are low (ICCAT 1999a). For bigeye tuna, the 1999 stock assessment indicates a decline in CPUE and suggests that the stock will continue to decrease in abundance if current catch levels are maintained (ICCAT 1999b). It is unlikely that these two fisheries will increase.

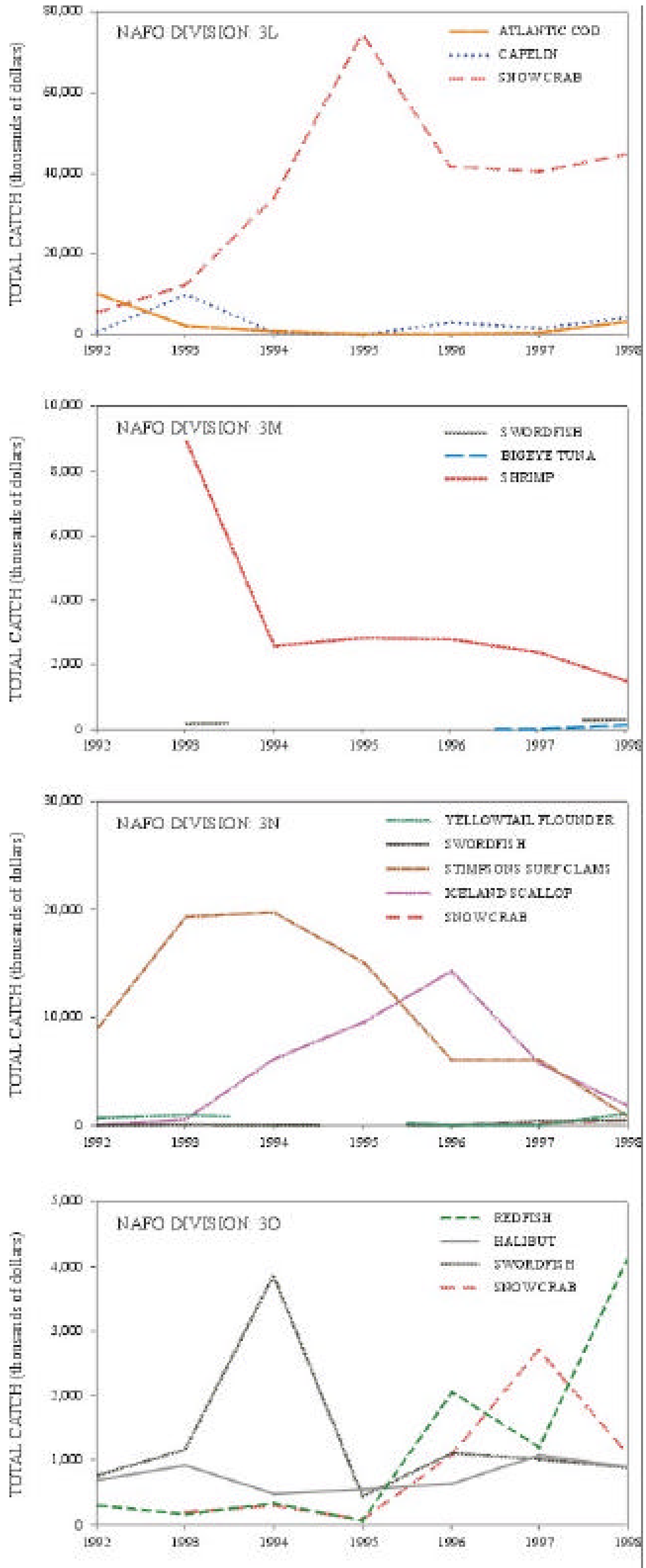
Figure 7.1-3 Catch (Cnd$) by Main Species per NAFO Division

(a) Percent of Total Catch (Cnd$) by Main Species per NAFO division, 1998.



Appendices.cdr (pg 6) 29JUN00 Figure 7.1-3a

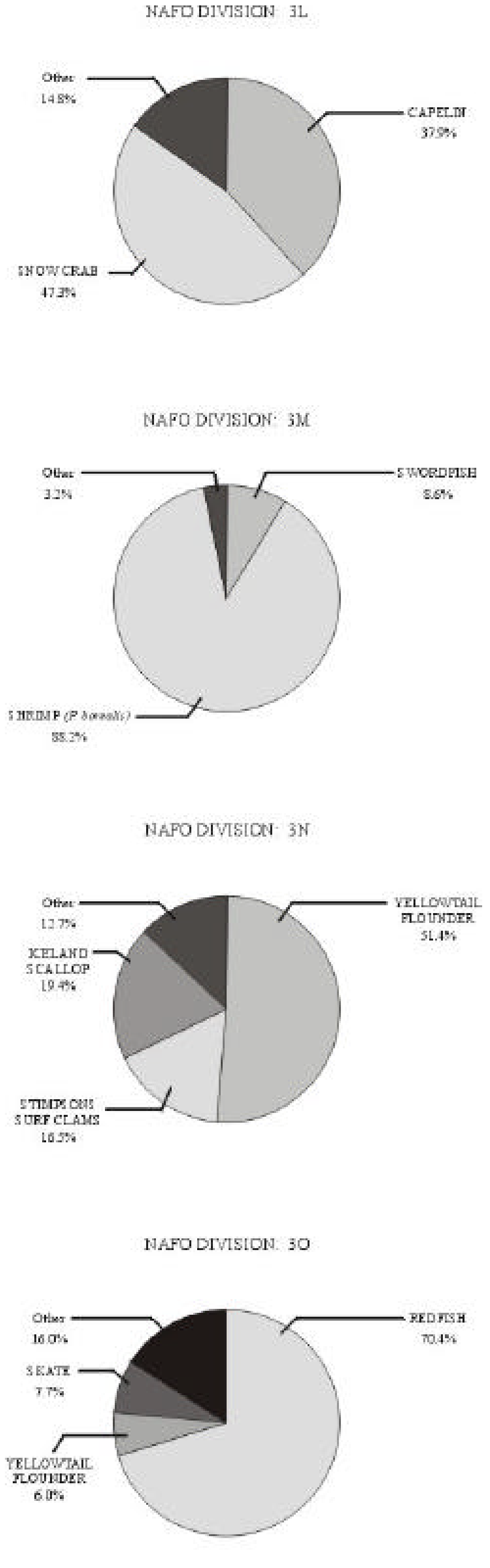
(b) Trends in Catch for Main Species (Cnd$) per NAFO Division



Appendices.cdr (pg 6) 29JUN00 Figure 7.1-3b

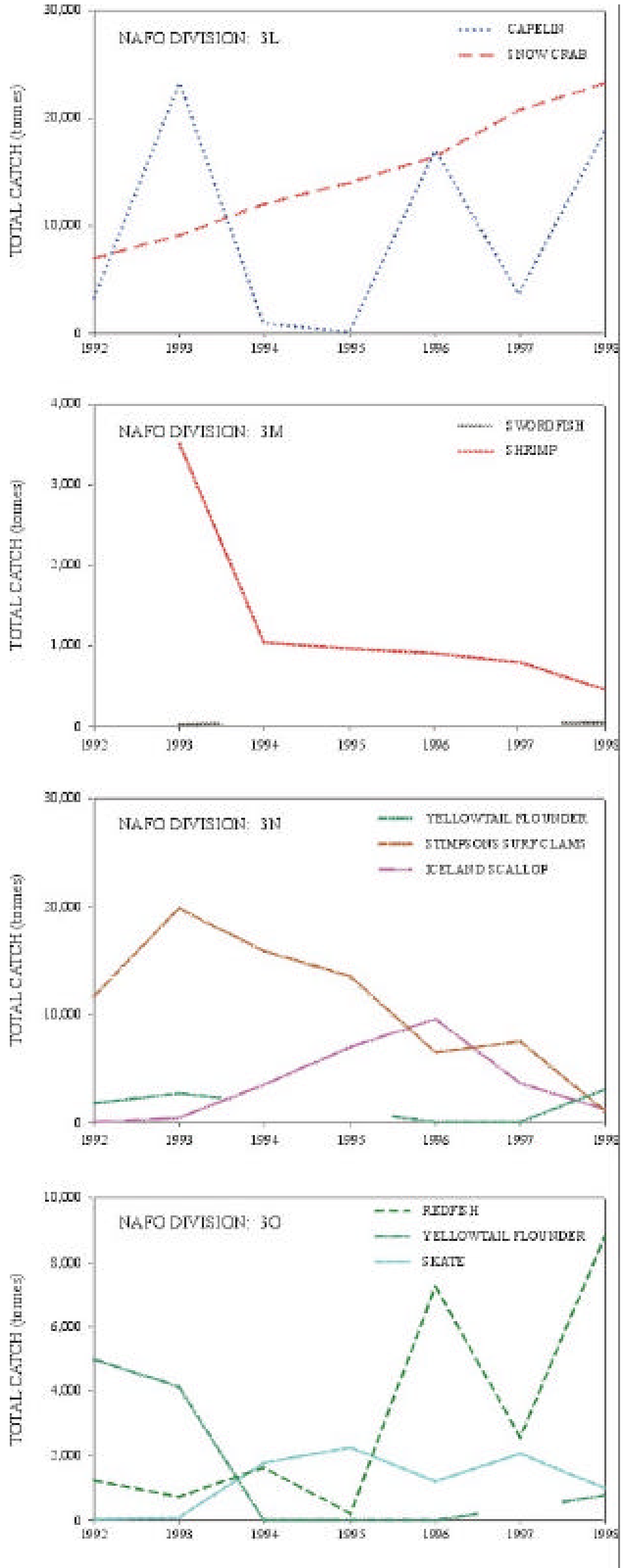
Figure 7.1-4 Catch (tonnes) by Main Species per NAFO Division

(a) Percent of Total Catch (tonnes) by Main Species per NAFO division, 1998.



Appendices.cdr (pg.7) 29JUN00 Figure 7.1-4a

(b) Trends in Catch for Main Species (tonnes) per NAFO Division



Appendices.cdr (pg.7) 29JUN00 Figure 7.1-4b

Total fisheries landings in 3N have declined since 1994 (Figures 7.1-3b and 7.1-4b). Iceland scallop catches in Lilly and Carson Canyon areas have declined by 10 percent in each of the last three years. The fishery in each area appears to have been driven by an accumulation of larger, higher-priced scallops (DFO Integrated Management Plan - Iceland Scallop 1999). The fishery for yellowtail flounder in 3N (as well as 3O) will likely increase. A directed fishery for yellowtail was re-opened in 1998 in 3LNO. Based on CPUE data and research vessel surveys, the stock appears to be at a level close to that of the mid-1980s (NAFO Scientific Council 1999a; 1999b; Kulka 1999). Yellowtail distribution and, therefore, fishing distribution is concentrated in 3NO rather than 3L. Stimpsons surf clam catches peaked in 3N in 1996 and have since declined (Figures 7.1-3b and 7.1-4b). Very little published information is available on this fishery. Clams are generally fished on the tail of the Grand Banks (3NO) in relatively shallow (50 to 75 m) water (R. Coombs, pers. comm.).

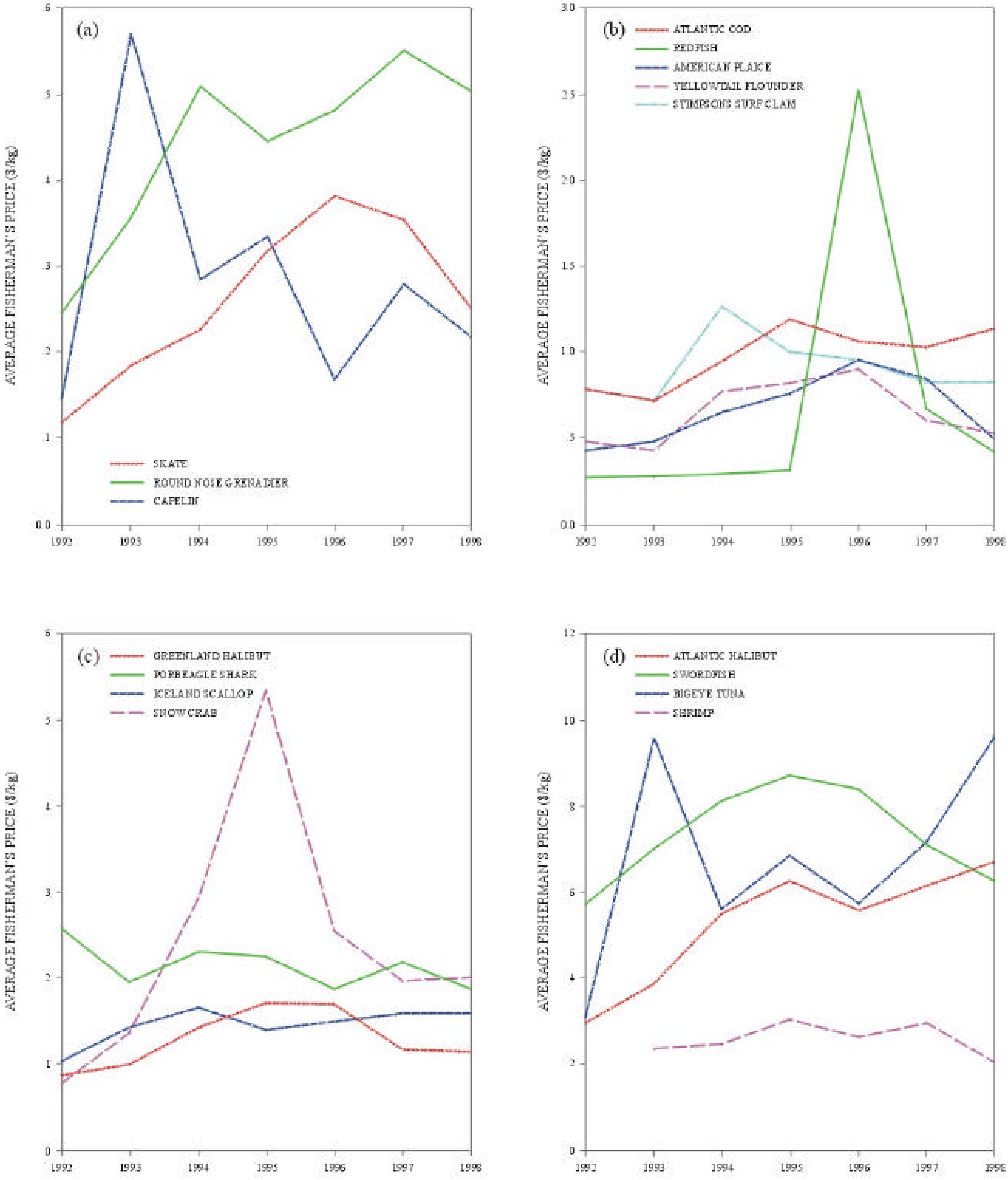
Redfish catches have increased in 3O since 1995 (Figures 7.1-3b and 7.1-4b). Research vessel surveys suggest that the redfish stock in 3O has increased since the early 1990s and stabilized since 1994 (DFO Stock Status Report A1-01 1999). Thorny skate catches in 3O have been relatively stable since 1994 (Figure 7.1-5b). Research vessel surveys indicate that the skate population is healthy (Kulka and Mowbray 1998). Skate prices, however, are quite low (Figure 7.1-5) and it is unlikely that this fishery will increase in size unless other fisheries are depleted or prices improve. Atlantic halibut catches have also remained stable in this NAFO area (Figure 7.1-3b). Atlantic halibut are under TAC restrictions and quotas are typically met. There are indications that halibut abundance is lower than it has been historically, particularly on the southern Grand Banks (DFO Science Stock Status Report A3-23 1997). The fishery in 3O will likely not increase.

Among other fish species, Greenland halibut (turbot) abundance is increasing in divisions 3KLMNO (NAFO Scientific Council 1999a; 1999b). In 3L, this fish is typically caught in deep water around the Flemish Pass.

Fisheries respond to catch restrictions (usually TAC) and to market prices. Of commonly caught species in recent years, consistent price increases have occurred only for bigeye tuna and Atlantic halibut (Figure 7.1-5). As noted above, abundance for both bigeye tuna and Atlantic halibut is likely decreasing. It is therefore unlikely that larger catches will be allowed. Based on available price trends (1992 to 1998), there is no reason to expect that the Grand Banks fisheries will change markedly based solely on landed value of catches.

Figure 7.1-5 Average Price for Common Species Fished on the Newfoundland Grand Banks and All Species in 3Lt

Figures (a) to (d) range from lower to higher priced species.



Appendices.cdr (pg1) 29JUN00 Figure 7.1-5

Industry Structure

The fishery in 3L is predominantly a fixed gear (crab pot) fishery and is mostly conducted by Newfoundland, with vessels under 35 ft fishing closer to shore. The most intensive fishing activity typically occurs between June and September (Figures 7.1-6 to 7.1-9).

In 3M, the Canadian fishery is predominantly a mobile gear (shrimp trawl) fishery. The fishery is conducted by both Newfoundland and Nova Scotia, with vessels over 65 ft and more commonly, with vessels over 125 ft (Figures 7.1-6 to 7.1-8). These vessels are owned for the most part by large vertically integrated companies (FPI and Highliner Foods fisheries, for example). The fishing season is shorter in 3M than in other NAFO divisions. In 1998, it extended from June to August (Figure 7.1-9).

The fishery in 3N is predominantly a mobile gear (scallop dragger and groundfish trawl) fishery and is conducted mostly by Newfoundland, with vessels 35 to 45 ft in length. In 1998, an increase in the number of trips by vessels greater than 125 ft reflects the opening of the yellowtail fishery. The bulk of the fishers activity occurs between June and September (Figures 7.1-6 to 7.1-9).

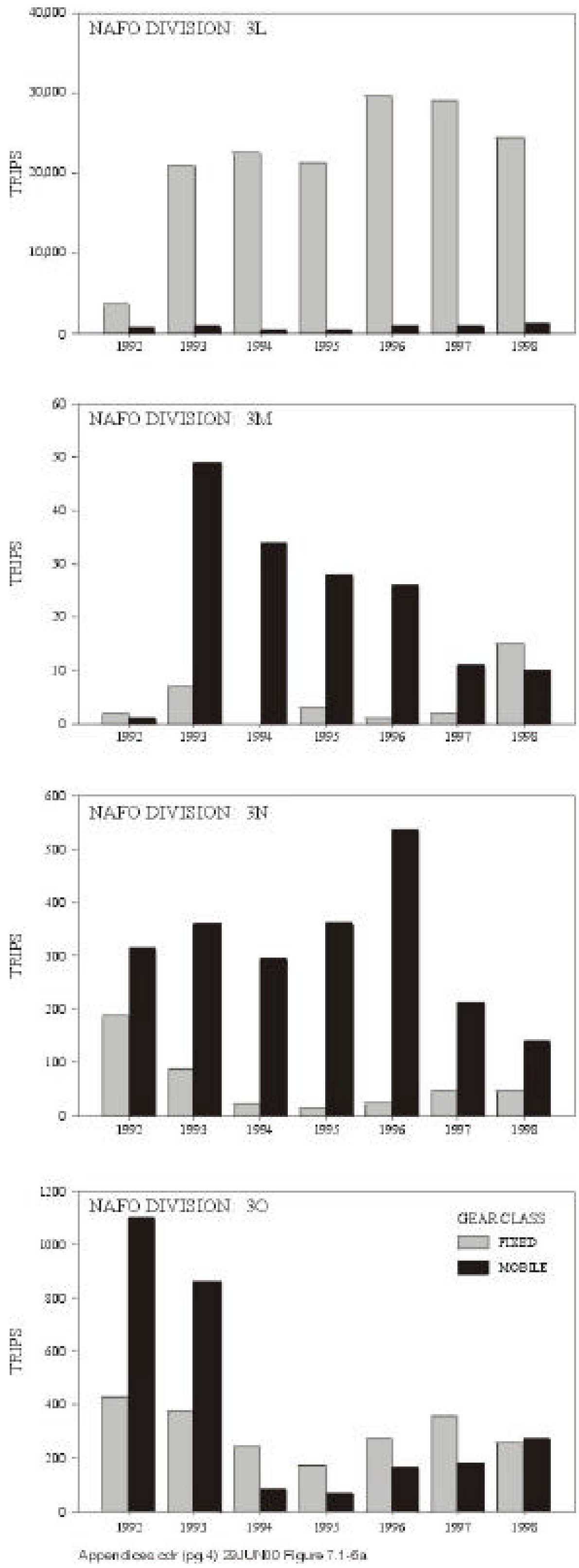
The fishery in 3O is more diverse and this is reflected in the use of both mobile and fixed gear. Of the main catches, crab is the only fixed gear fishery. Most of the fishery is conducted by Newfoundland. Most trips are made with vessels 35 to 45 ft but all vessel lengths are common. The bulk of the fishing activity occurs from May to September (Figures 7.1-6 to 7.1-9).

The number of people employed in fish harvesting in Newfoundland has remained relatively stable since 1995. The annual average for 1999 was 8,700 employed, with peak employment at 10,300 (Table 7.1-2). In 2000, 16,000 fishers were registered with the Professional Fish Harvesters Certification Board. Overall, the number of Newfoundland-owned vessels smaller than 65 ft fishing the Grand Banks has increased since 1992 and the number of vessels greater than 125 ft has decreased from 58 to 14 in 1998 (Figure 7.1-10).

In general, the shrimp and current groundfish fisheries are conducted by large operators, while the crab and scallop fisheries are conducted by smaller operators. Processing of shrimp on larger vessels is done at sea, while smaller vessels bring shrimp to shore to be processed. Scallops are shucked at sea and packaged on shore. Groundfish, crab and most other species are processed on shore. There are over 100 (core and non-core) processing plants in Newfoundland (Figure 7.1-11), employing an average of 8,400 people, with peak employment at 16,700. The number of people employed in fish processing has more than doubled since 1995 (Table 7.1-2).

Figure 7.1-6 Trips and Catch by Gear Type by NAFO Division

(a) Trips by Gear Type



(b) Catch (Cnd$) by Gear Type

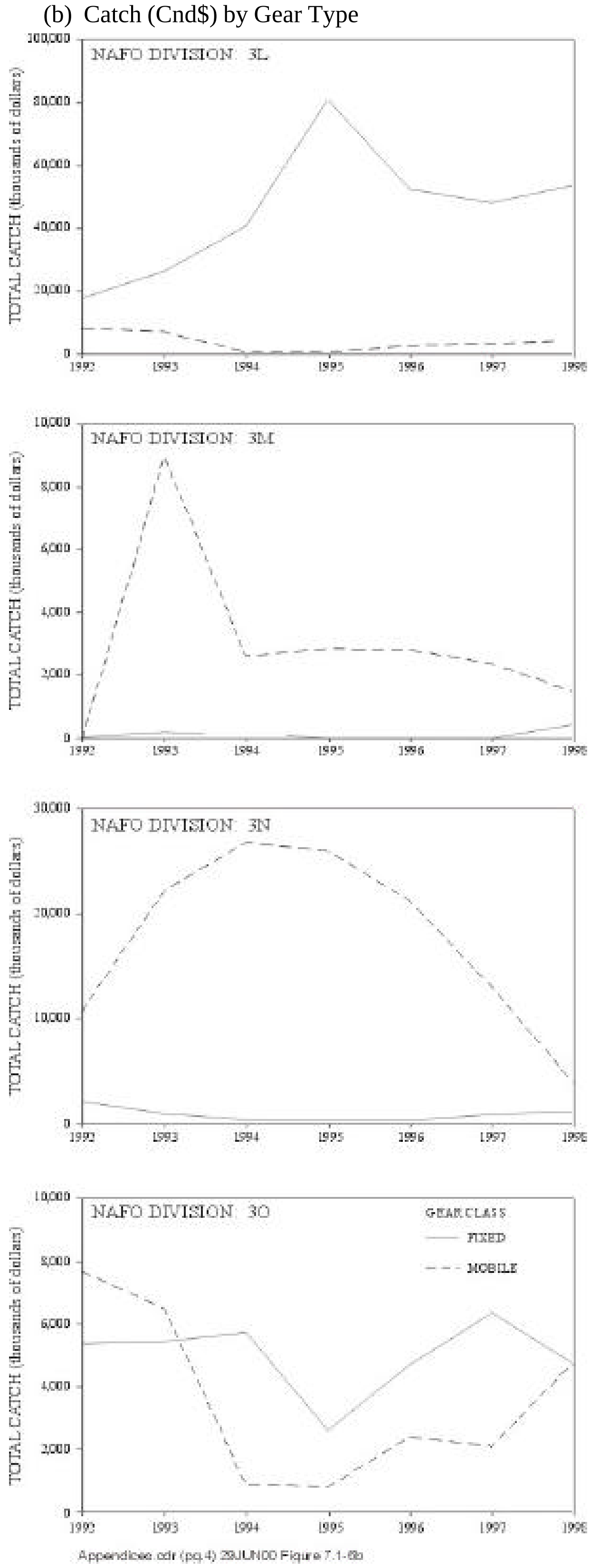
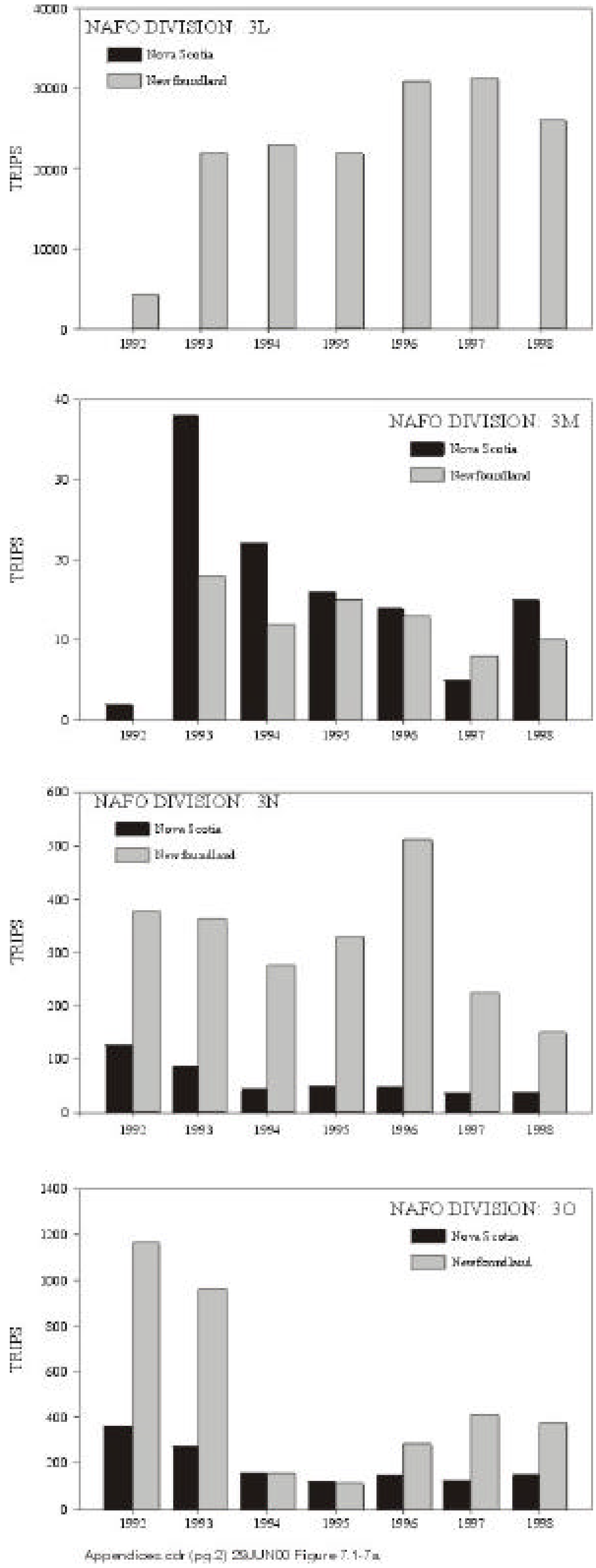


Figure 7.1-7 Trips and Catch by Province by NAFO Division

(a) Trips by Province
(Not showing, trips by PEI, NB and Quebec (4 trips total))



(b) Catch by Province
(Quebec catch in 3M in 1993 ($\$177 \times 10^3$). Catches by NB and PEI were negligible).

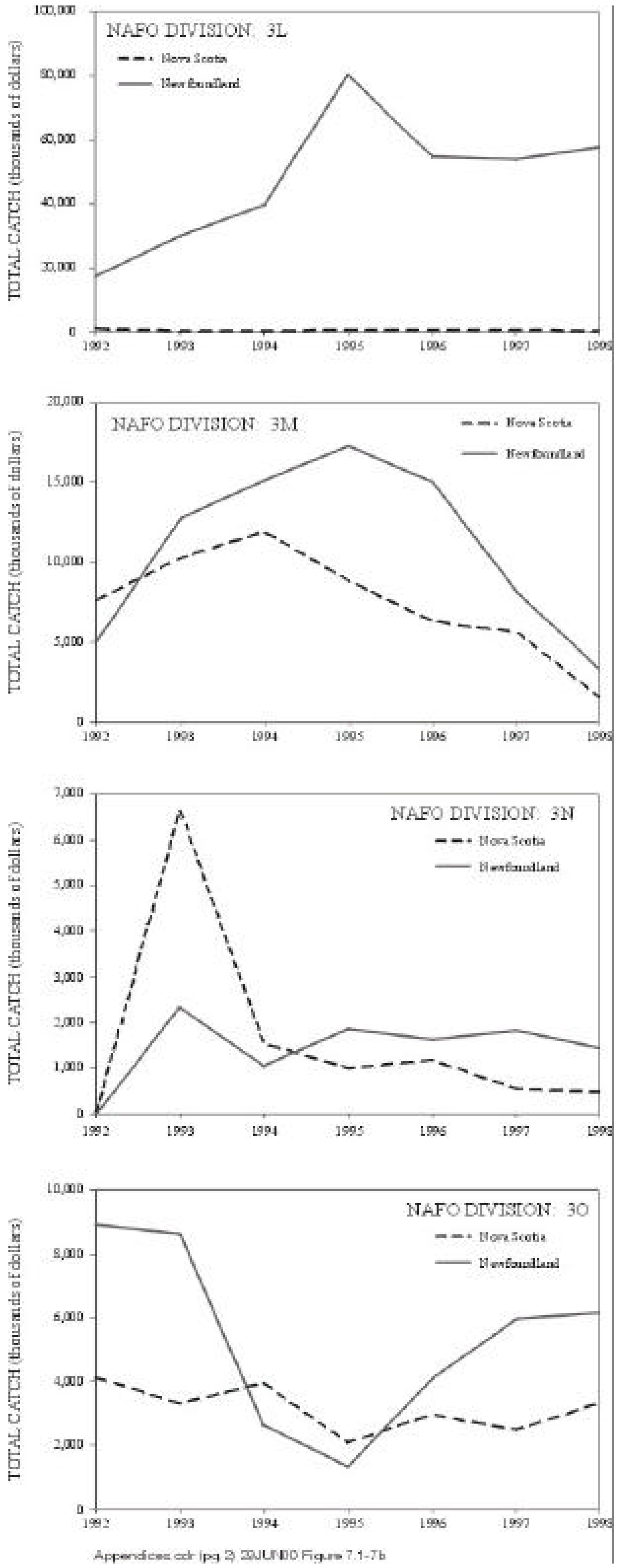
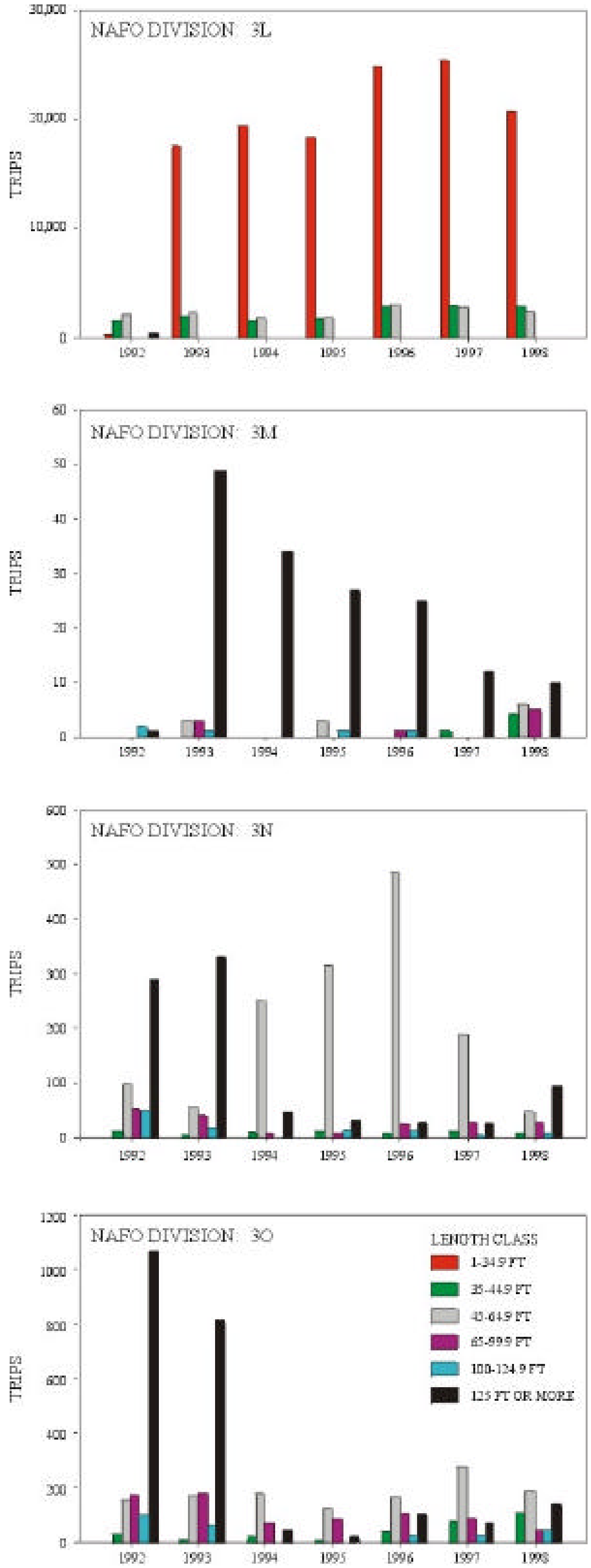


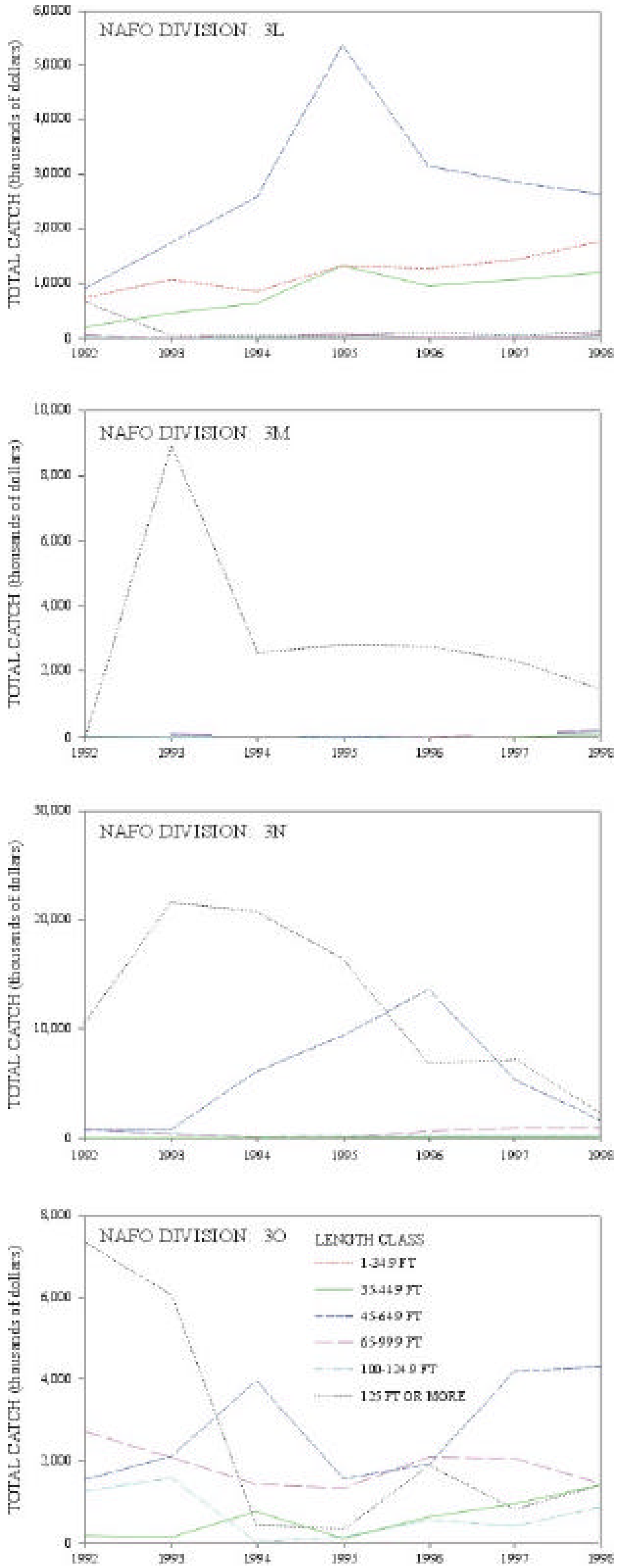
Figure 7.1-8 Vessel Length by NAFO Division

(a) Trips by Vessel Length



Appendices.cdr (pg.3) 23JUN00 Figure 7.1-8a

(b) Catch (Cnd$) by Vessel Length



Appendices.cdr (pg.3) 23JUN00 Figure 7.1-8b

Figure 7.1-9 Fishing Season by NAFO Division

Boxes identify the time period over which 50% of trips are made. For example, 50% of trips in 3O were made between May and August in 1992. Whiskers represent earliest and latest trip dates excluding trip dates outside the norm (outliers and extremes). Where whiskers appear to be missing, the distribution is highly skewed (3M in 1992, 1994 and 1996).

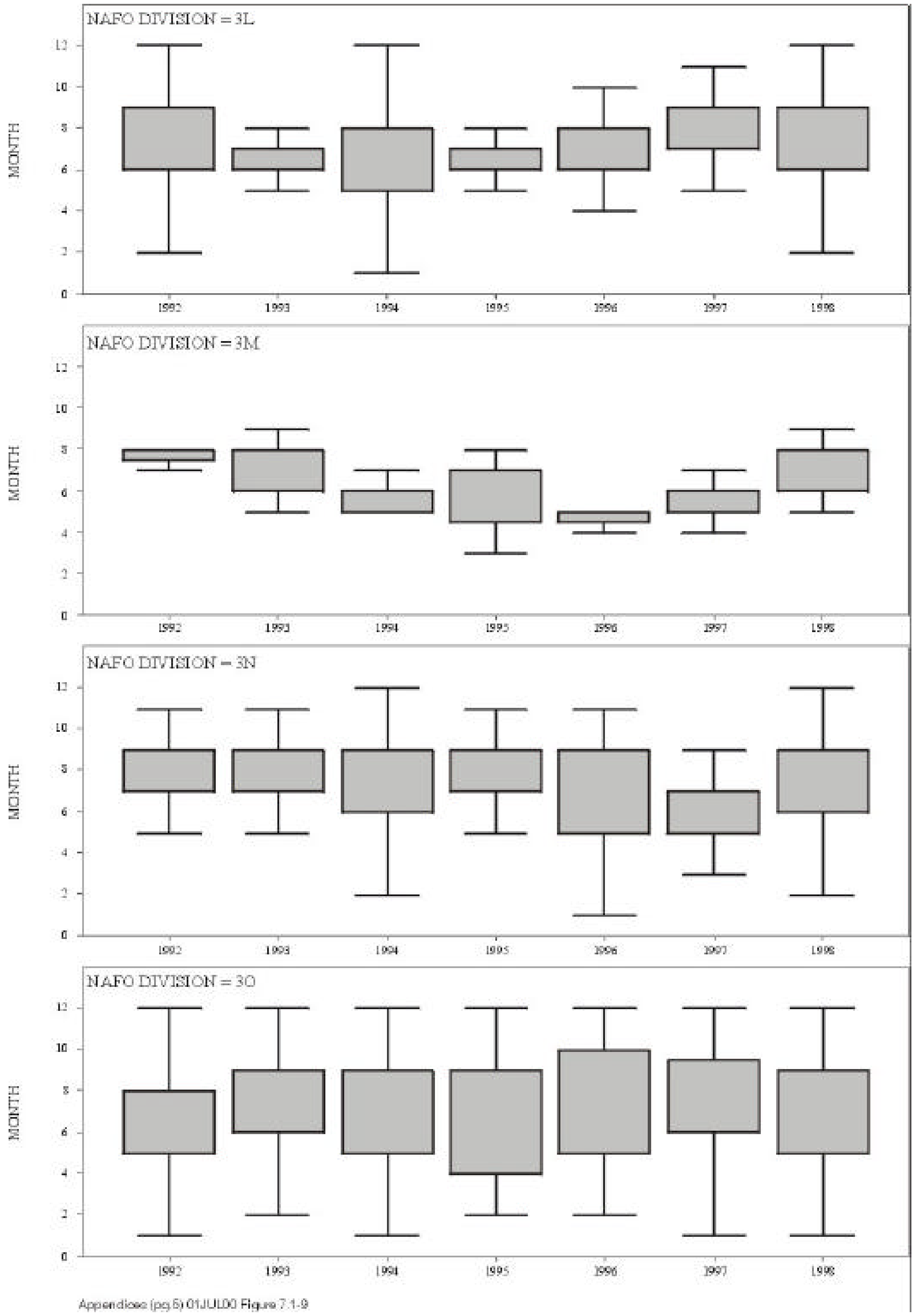
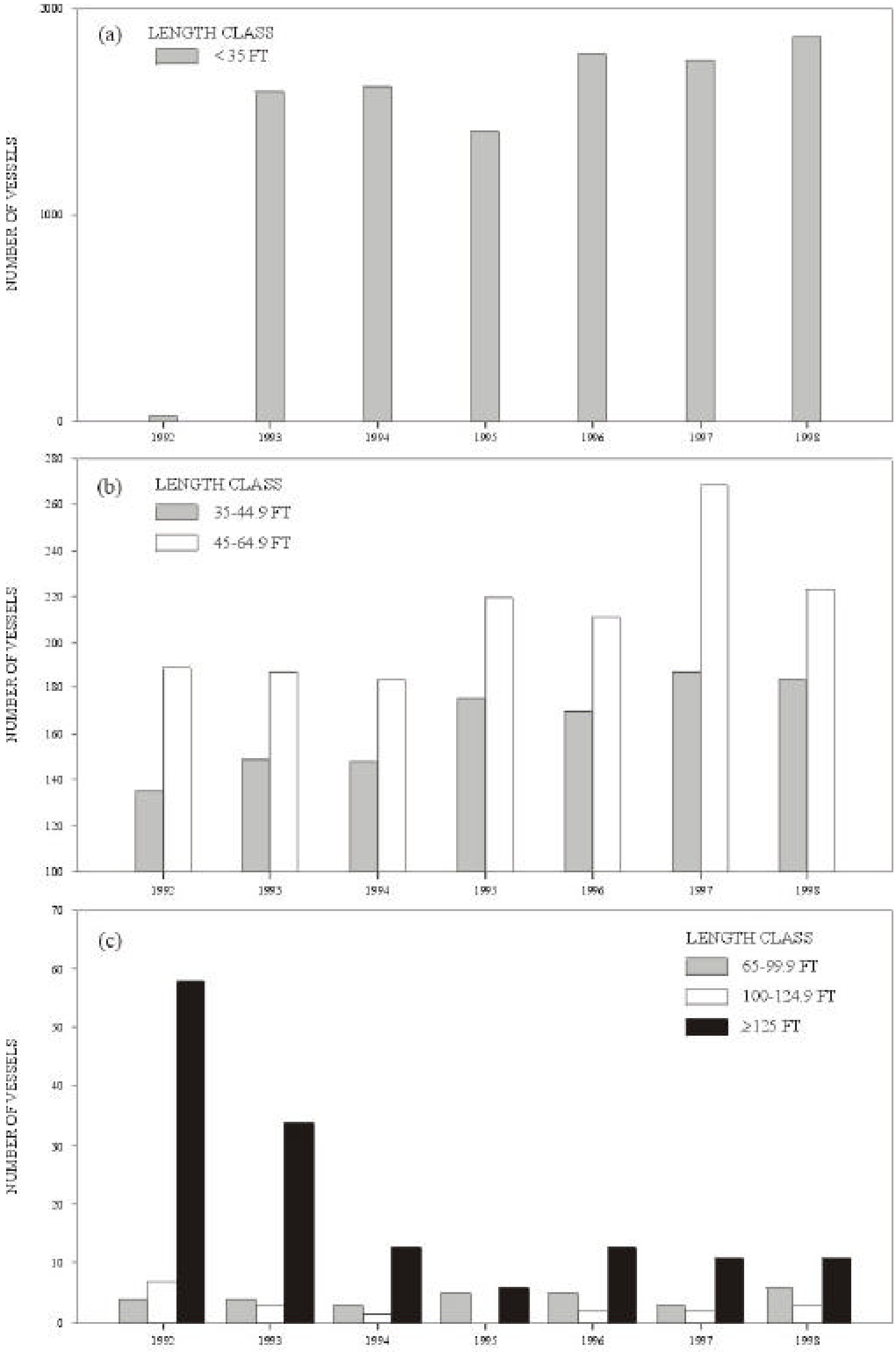


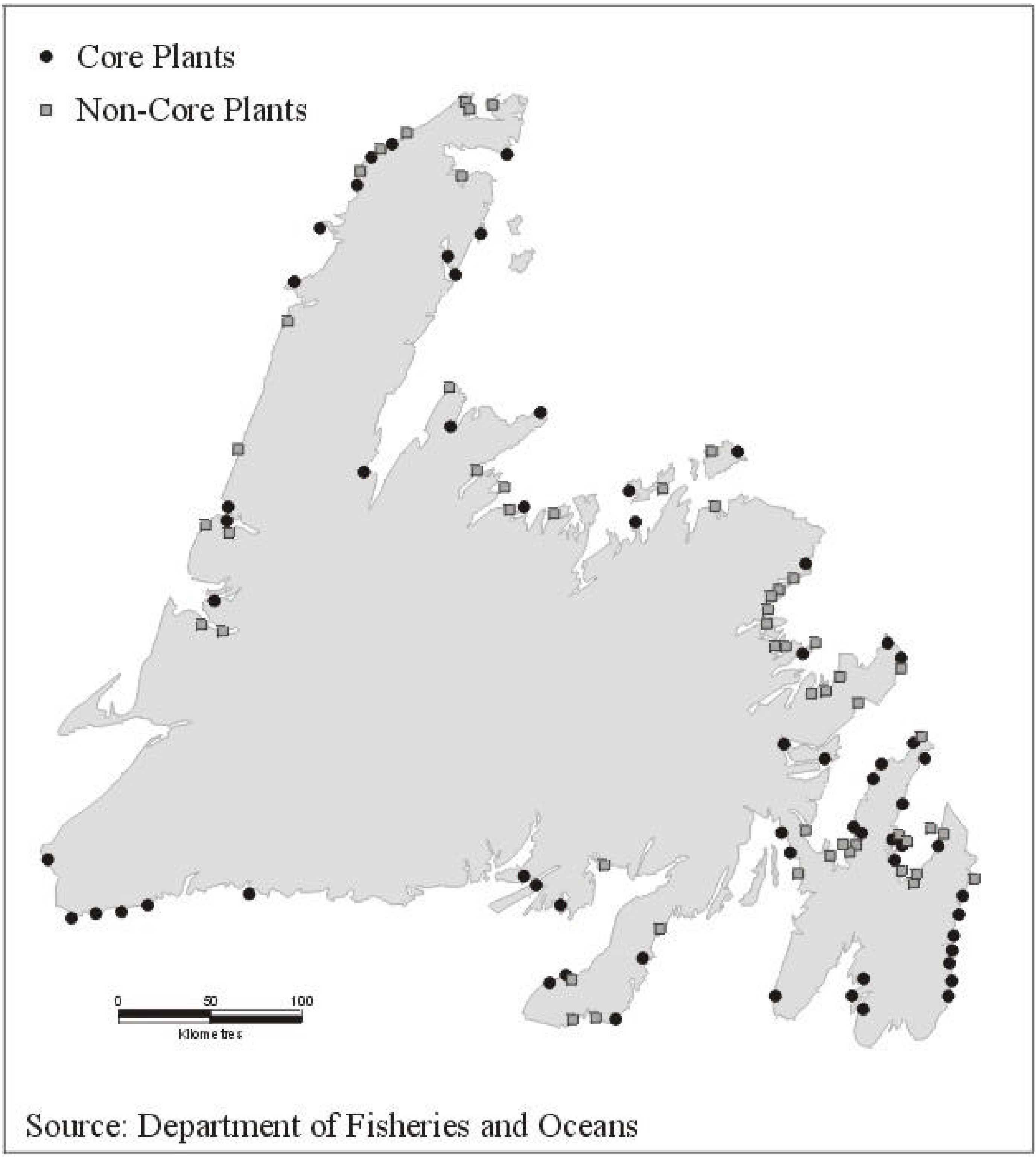
Figure 7.1-10 Number of Newfoundland Owned Vessels by Length Class

(a) Vessel length less than 35 ft;
(b) Vessel length 35 ft to 65 ft; and
(c) Vessel length 65 ft and greater.



Appendices.cdr (pg 8) 29JUN00 Figure 7.1-10

Figure 7.1-11 **Active Fish Plants 1999**



Appendices.cdr (pg.9) 29JUN00 Figure 7.1-11

Table 7.1–2 Employment Statistics for the Fisheries Processing and Harvesting Sector

	1995	1996	1997	1998	1999
Processing	7,500	9,500	10,000	13,200	16,700
Harvesting	11,200	11,400	10,500	12,300	10,300
Total	18,700	20,900	20,500	25,500	27,000
Source: Department of Fisheries and Aquaculture 1999/Statistics Canada Labour Force Survey					

7.1.2.4 Potential Fisheries Scenario on the Grand Banks (2000 to 2005)

Given current trends in fishing activity and management practices on the Grand Banks, it is likely that the crab fishery will continue, although at a reduced level. The shrimp fishery is likely to increase in NAFO division 3L. The yellowtail fishery will likely increase in 3NO. The Greenland halibut fishery will also likely increase in deeper offshore waters. Skate and redfish populations appear to be healthy in NAFO division 3O, but market prices might limit the harvest of these species. There is little indication that other traditional groundfish fisheries will recover on the Grand Banks within the next five years. Recovery for American plaice and northern cod, for instance, might require another five to twenty years (Rivard et al. 1999a; 1999b). Scallop and clam fisheries will likely remain at current levels. Swordfish and bigeye tuna fisheries may decrease.

With increased fishing on some groundfish species and shrimp, the number of Newfoundland-owned vessels greater than 125 ft might increase. FPI's shrimp fleet, for instance, is currently operating at maximum capacity, although its groundfish trawler fleet is not. Based on employment trends over the past five years and the Province's continuing interest in fisheries product enhancement, the processing sector is expected to generate more new jobs than the harvesting sector.

7.1.2.5 Fisheries in the White Rose Area

In brief, fisheries catches are typically lower in the affected area (3Lt) than elsewhere in 3L. Important fisheries (existing and anticipated) near White Rose include: crab, shrimp and Greenland halibut, and perhaps American plaice and northern cod during the latter part of the operations and decommissioning phases of the Project. Shrimp and Greenland halibut concentrations are not found in the immediate vicinity of White Rose, but rather, further offshore. Catch data from research vessel surveys do not indicate that the fishable area around White Rose will generate new fisheries in the near future. A more detailed description of fisheries in 3Lt follows.

Although catches in NAFO division 3L are greater than in 3M, 3N and 3O, the bulk of the 3L fishery is located closer to shore (Figures 7.1-12 and 7.1-13). Of the catches at the offshore edge of 3L, catches are highest to the north of 3Lt, in unit area 3Li (Figure 7.1-14). Overall, catches in 3Lt made up only 1 percent of total catches (by value) in 3L from 1992 to 1998.

Snow crab is by far the most important fishery in 3Lt (97.9 percent of landed value), although there was an important Iceland scallop fishery in the area before 1997 (Figures 7.1-15). Historically, cod and American plaice were the main fisheries in 3Lt, as they were in the remainder of the 3L.

Crab has been fished in 3Lt since 1995, mostly by Newfoundland fishers, with vessels 45 to 65 ft in length (Figures 7.1-15 to 7.1-18). Since 1995, the fishing season has started as early as May and ended as late as September (Figure 7.1-19). Three areas have been fished for crab near White Rose. The closest area is approximately 25 km northeast of the Project area, while the other two are more than 50 km away (Figure 7.1-20). Data from the 1999 exploratory fishery for crab in 3Lt (D. Taylor, pers. comm.) show additional fishing activity at depths ranging from 200 to 300 m (around the 200-mile limit) but no change in crab fishing activity in the immediate vicinity of White Rose. As noted above, exploratory fisheries in this area have been reduced for 2000.

There is a small porbeagle shark fishery in 3Lt (Figure 7.1-15) and less than $20,000 was landed in 1998. Newfoundland fishers have little interest in the fishery and it is harvested exclusively by Nova Scotia fishers. The porbeagle shark population in the Northwest Atlantic is in a state of decline. Recent stock abundance estimates show that the population is approximately 15 to 20 percent of the size of the population prior to the onset of harvesting (1960s) (Campana et al. 1999). The fishery will not increase; it will more likely be restricted.

The Iceland scallop fishery was important in 3Lt from 1993 to 1996 (Figure 7.1-15). A renewed scallop fishery is unlikely unless other fisheries are exhausted or scallop prices increase dramatically. The scallop fishery is difficult and tends to be a fishery of last resort. For instance, only 135 t of scallop were fished out of a TAC of 7,000 t on the entire Newfoundland shelf last year. The most important aggregations of Iceland scallops, as well as Stimpsons surf clams, are more than 150 km to the southwest of White Rose (DFO Science Stock Status Report C2-07 1999).

Cod landed in 3Lt (Figure 7.1-15) are by-catch. There is no directed fishery for cod in the offshore. As noted previously, northern cod and American plaice may not recur as directed fisheries on the Grand Banks (or in 3Lt) for another five to twenty years (Rivard et al. 1999a; 1999b). Any conclusions on the exact timing of recovery as well as on the distribution of recovered fisheries are speculative at this time.

Figure 7.1-12 Total Catch per NAFO Division

(a) Total Catch (Cnd$) (b) Total Catch (tonnes)

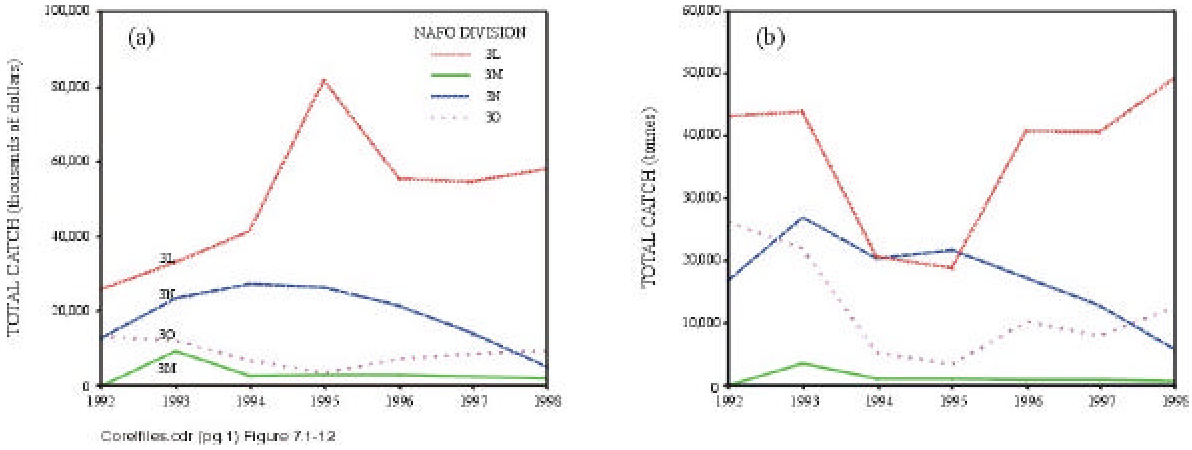


Figure 7.1-13 Total Catch in 3L with Increasing Distance from Shore

(a) Total Catch (Cnd$) (b) Total Catch (tonnes)

Distance Categories: Nearshore = 3L (a,b,f,j,q); 100 km = 3L (c,g,s); 200 km = 3L (d,h,r); Shelf Edge = 3L (e,i,t); Flemish Cap = 3M (a,b,c,d)

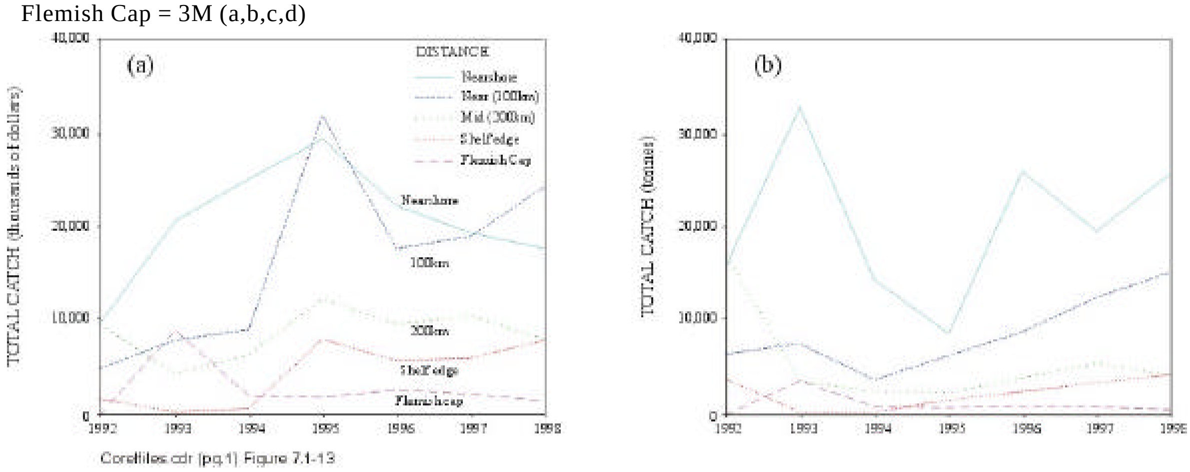


Figure 7.1-14 Total Catch per NAFO Unit Area on the Shelf Edge

(a) Total Catch (Cnd$) (b) Total Catch (tonnes)

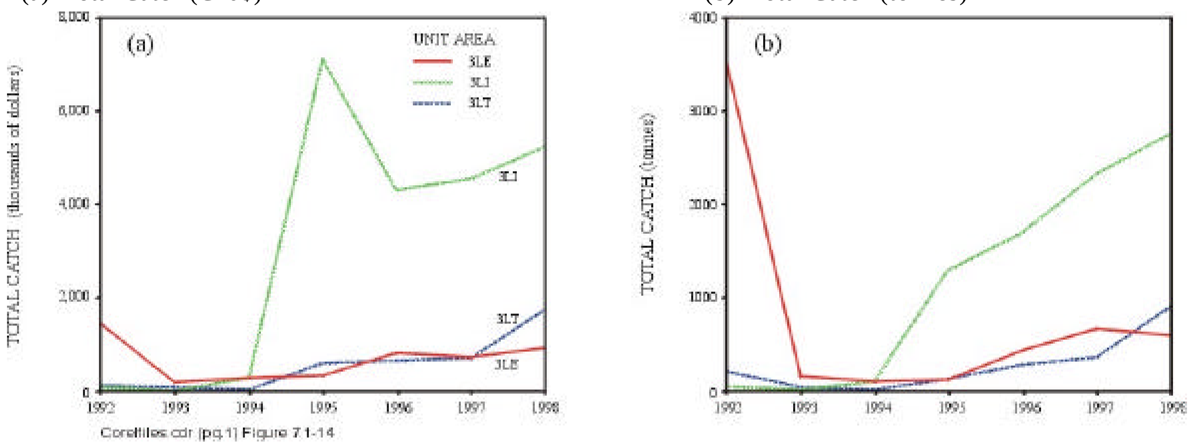


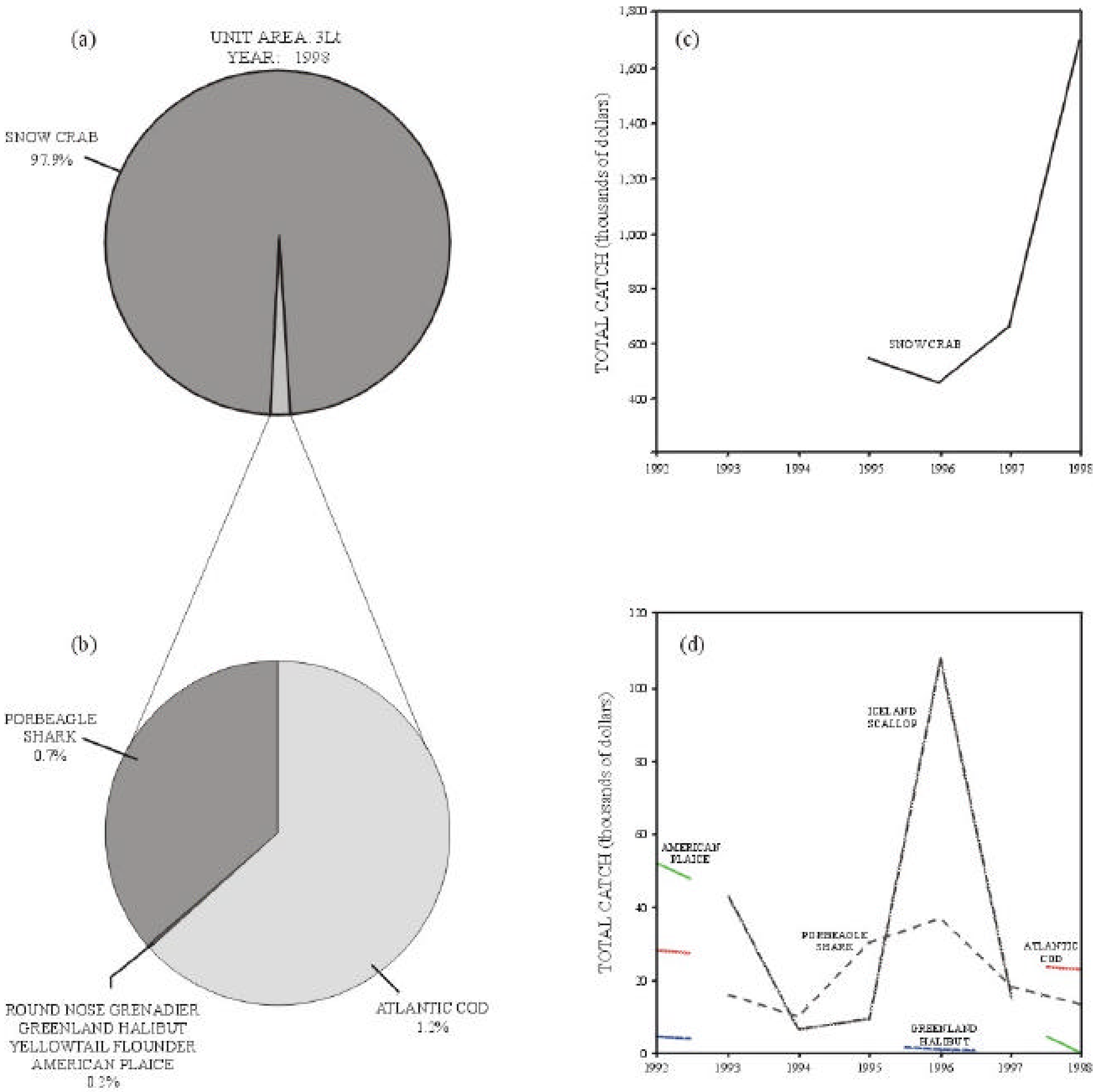
Figure 7.1-15 Snow Crab Catch in 3Lt

(a) Percent of Total Catch (Cnd$) for Snow Crab in 3Lt in 1998

(b) Percent of Catches (Cnd$) for Species Making up Remaining Fraction of Catches

(c) Trends in Catch (Cnd$) for Snow Crab in 3Lt from 1992 to 1998

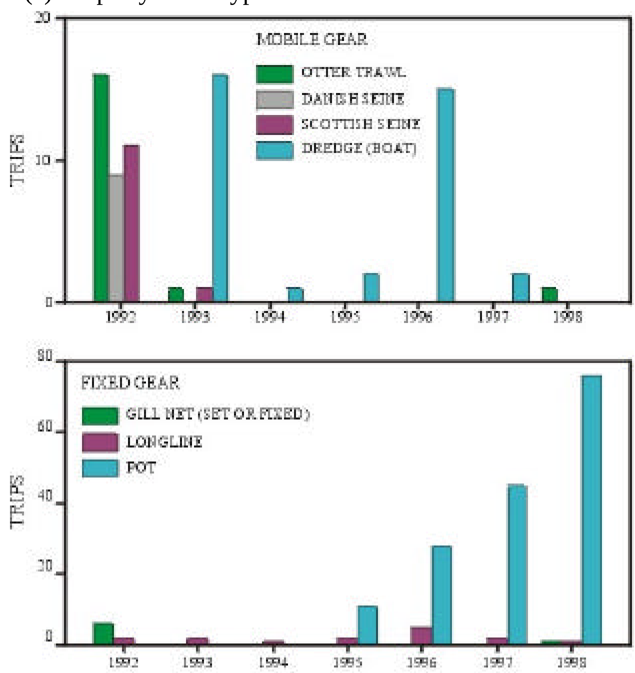
(d) Trend in Catches (Cnd$) for Other Important Species



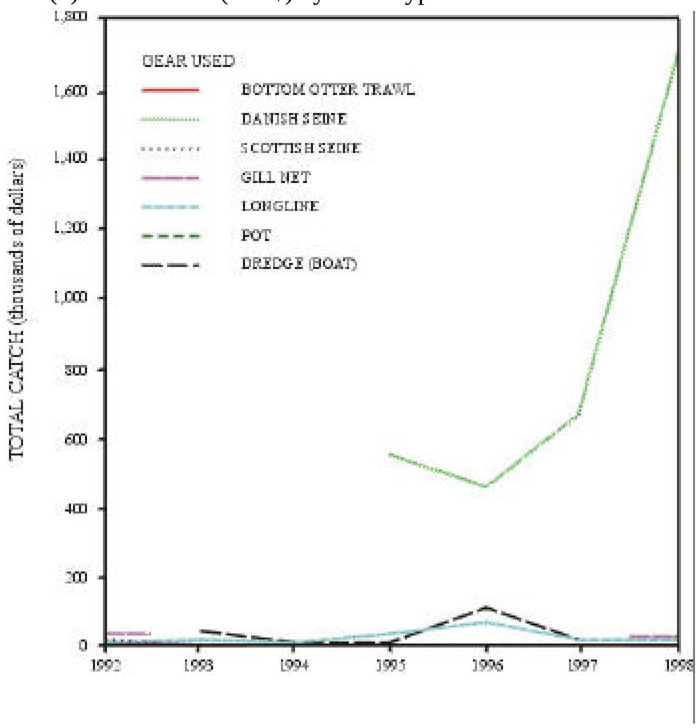
Corelfiles.cdr (pg 2) Figure 7.1-15

Figure 7.1-16 Gear Type in 3Lt

(a) Trips by Gear Type in 3Lt-Mobile and Fixed Gear

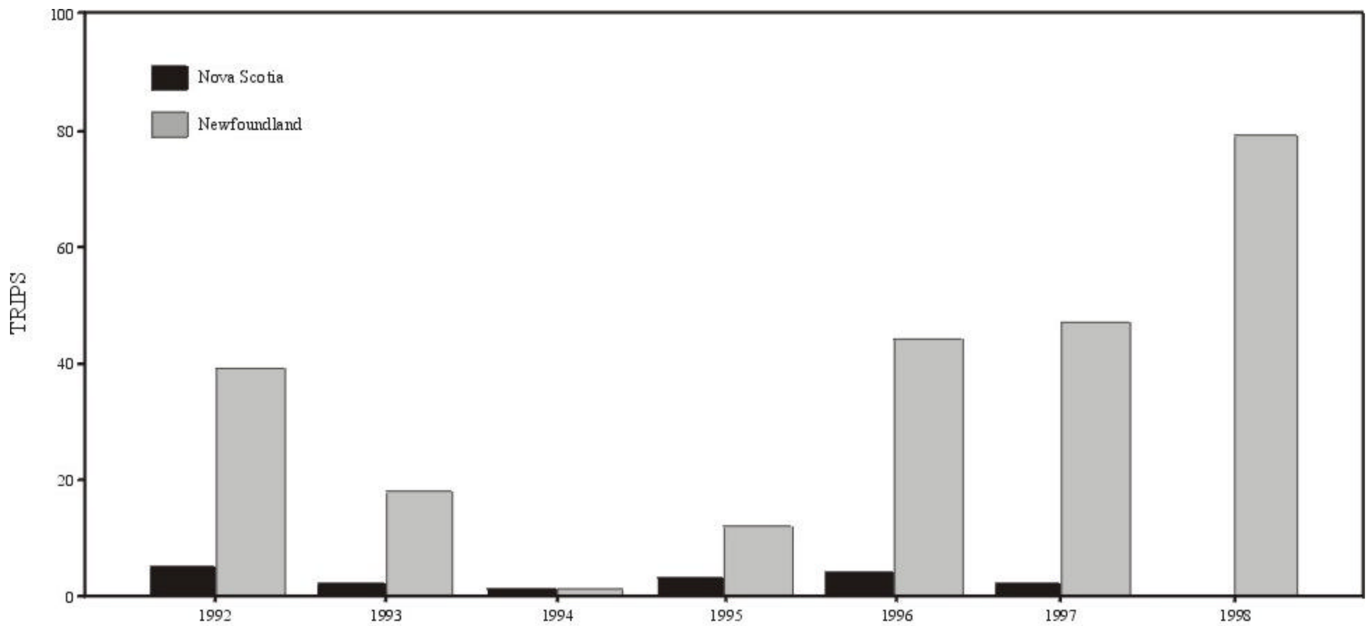


(b) Total Catch (Cnd$) by Gear Type



Corelfiles.cdr (pg.3) Figure 7.1-16

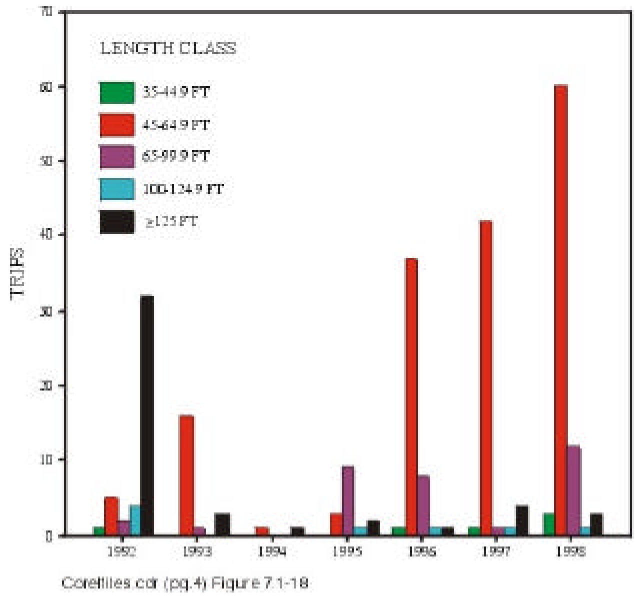
Figure 7.1-17 Trips by Province in 3Lt



Corelfiles.cdr (pg.3) Figure 7.1-17

Figure 7.1-18 Vessel Length in 3Lt

(a) Trips by Vessel Length in 3Lt



(b) Catch (Cnd$) by Vessel Length in 3Lt

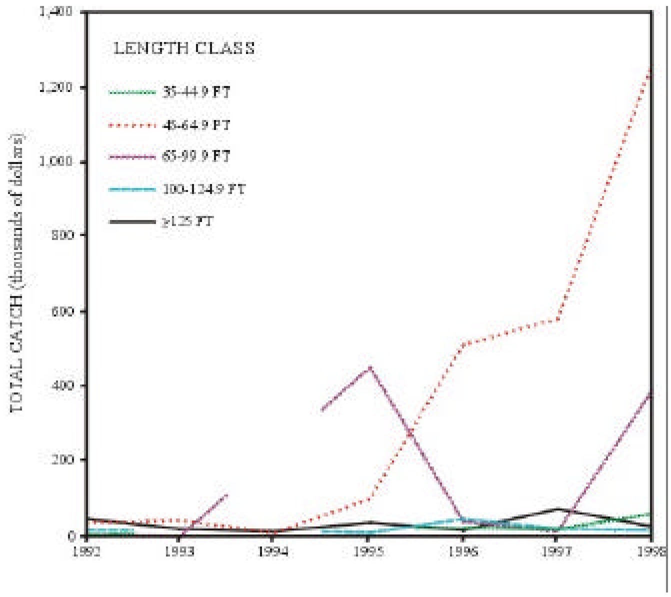


Figure 7.1-19 Fishing Season in 3Lt

Boxes identify the time period over which 50% of trips are made. For example, 50% of trips in 1992 were made between June and August. Whiskers represent earliest and latest trip dates excluding trip dates outside the norm (outliers and extremes). Where whiskers appear to be missing, the distribution is highly skewed (1993, 1994, 1997).

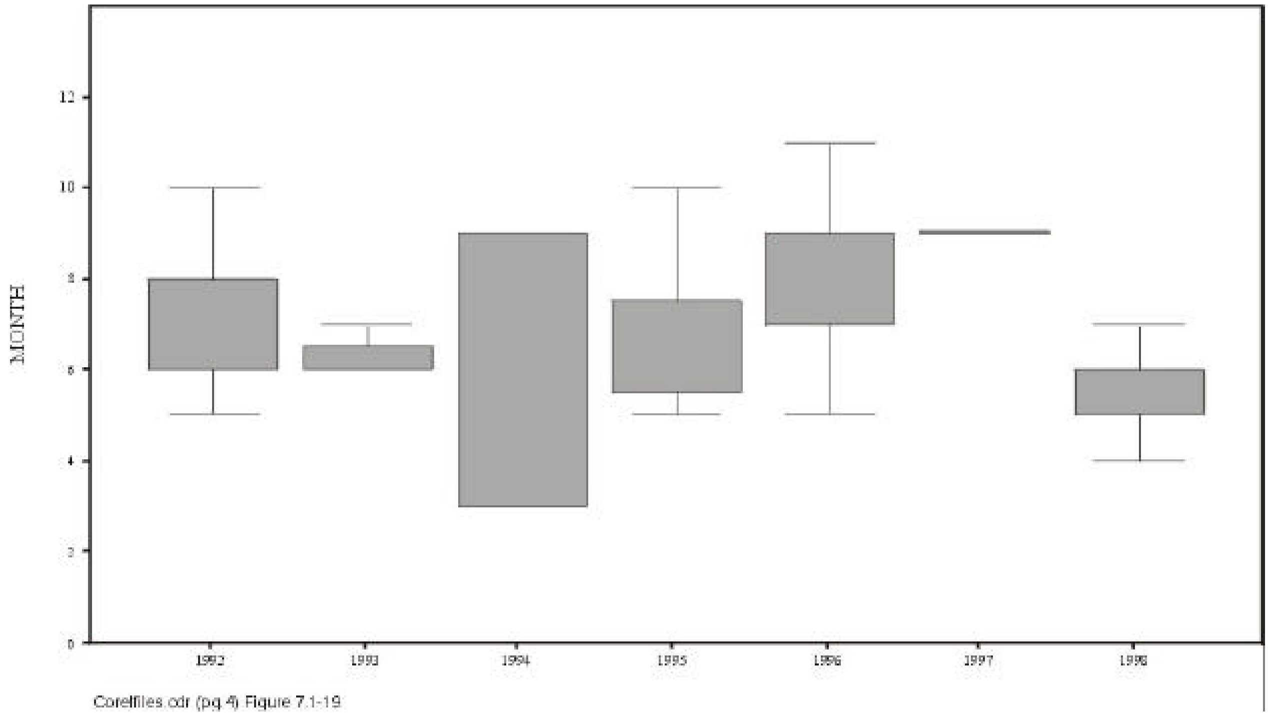
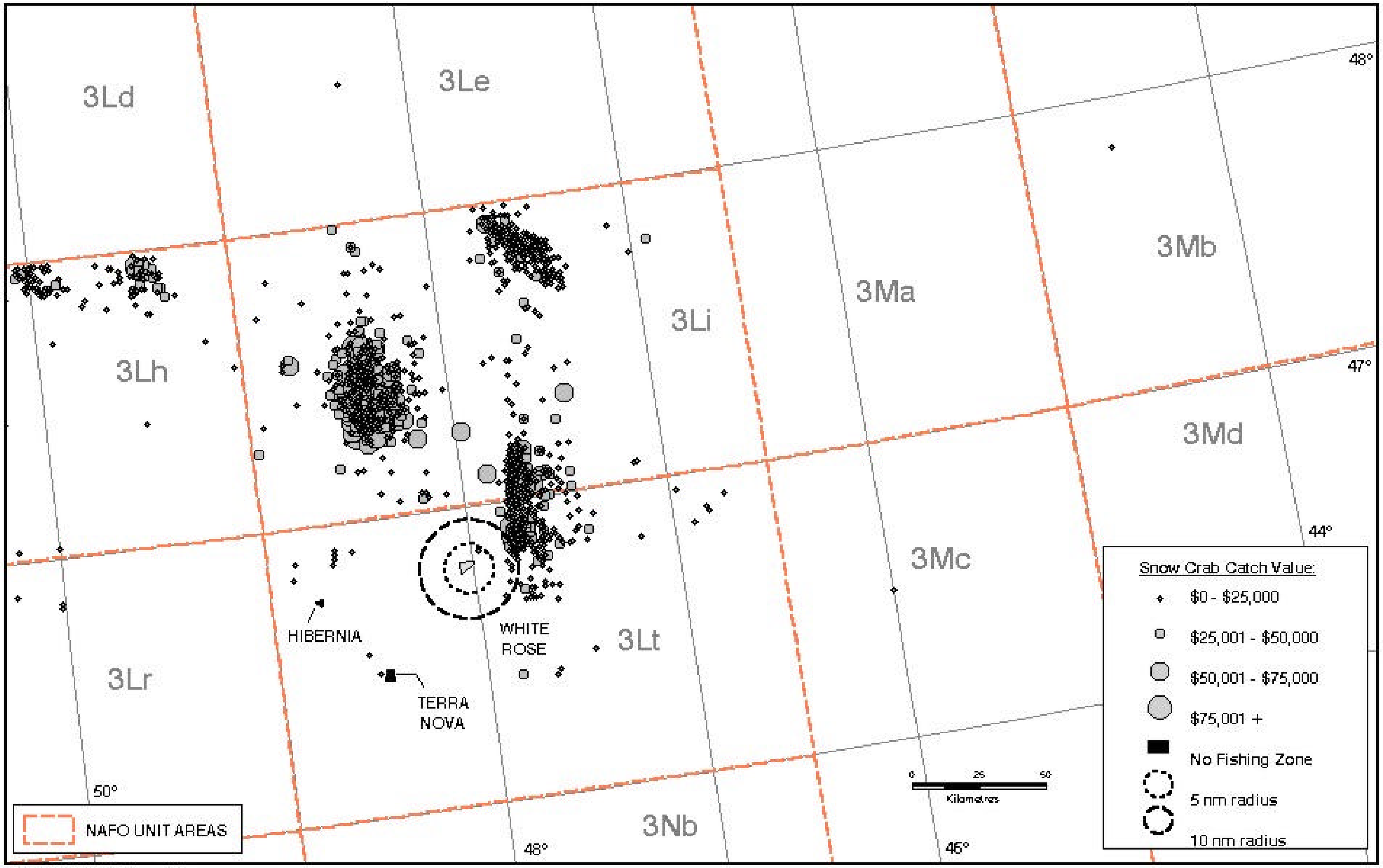


Figure 7.1-20 Geographic Distribution of Snow Crab Catches in the White Rose Area, 1995 to 1998 Total



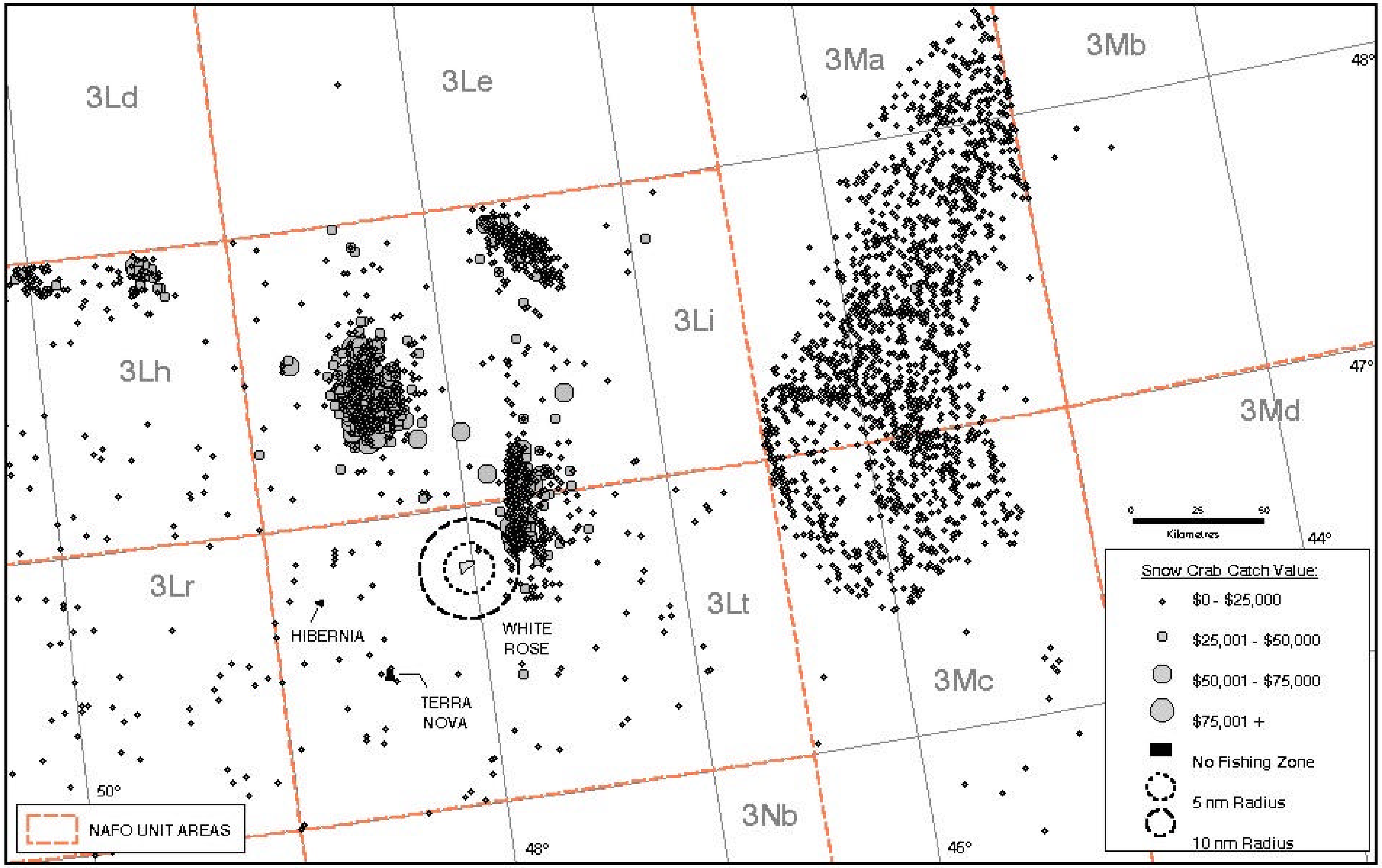
1401-13.WOR 14JUL00 Figure 7.1-20

Greenland halibut has been caught in 3Lt since 1992 (Figure 7.1-15). However, this species is typically caught further offshore in the Flemish Pass, more than 50 km east of White Rose.

Other than species commonly caught in existing fisheries, sponge and sand lance are the only two groups that occur with any frequency in 3Lt. Analysis of DFO research vessel data (1995 to 1998) collected in 3Lt was carried out as part of the Fisheries VEC analysis. Important species or groups (weight per tow) were identified. Average weight per tow across years for sand lance and sponge were: spring survey sand lance: 522 kg/tow; fall survey sand lance: 733 kg/tow; fall survey sponge: 7,085 kg/tow. It is very unlikely that these will become important fisheries in the near future.

A summary of the location of total catches around White Rose is shown in Figure 7.1-21. Catches in 3Lt are mostly crab (see also Figure 7.1-20) and catches in 3M are mostly shrimp. No fisheries catch data are available for shrimp in the immediate vicinity of White Rose because the fishery is only opening this year. However, from research vessel data, important shrimp aggregations are typically found in deeper water, at least 50 km east of White Rose (Orr et al. 1999).

Figure 7.1-21 Geographic Distribution of Total Fisheries Catches in the White Rose Area, 1995 to 1998 Total



1401-15.wor 14JUL00 Figure 7.1-21

7.2 ENVIRONMENTAL EFFECTS ASSESSMENT

7.2.1 Environmental Effects

Project-environmental effects interactions are summarized in Table 7.2-1. Effects on fisheries are predicted to be consistent across construction, operation and decommissioning phases of the Project and no distinction is made between these phases in the text that follows. Large oil spills are dealt with separately because of the amount of concern these low probability/high consequence accidental events generate. Effects of past, present and future projects or activities, including the Hibernia and Terra Nova developments, general marine transportation, seismic testing and exploration drilling, are dealt with under Cumulative Environmental Effects (Section 7.2.2).

Table 7.2–1 Project-Fisheries Environmental Effects Interaction

Project Activities and Physical Works	Loss of Access to Fishing Grounds	Damage to Gear or Vessels	Biophysical Effects of Ongoing Operations	Information Communication and Emergency Response
Construction and Installation				
Topsides Fabrication/Outfitting				
Subsea Units Fabrication				
Field Development/Installation	X	X	X	X
Operations				
Administration				
Supply Base/Warehousing				
Helicopter Transport				
Offshore Production/Marine Support	X	X	X	X
Decommissioning	X	X	X	X
Malfunctions/Accidents/Unplanned Events	X	X	X	X
Past/Present/Future Projects				
Construction				
Operation	X	X	X	X

7.2.1.1 Loss of Access to Fishing Grounds

The White Rose Project area is centred on -48°47’30.70” W, 46°47’30.70” N (Figure 7.1-1). Water depths in this area range from 115 to 130 m. A no-fishing zone will be in place around four glory holes and will cover an area of approximately 15.4 km^2. (Note, however, that an additional well centre could be developed at White Rose if small ancillary oil pools become viable, increasing the no-fishing zone to 45 km^2).

The no-fishing zone for White Rose is small relative to the total fishing area available in 3L, let alone the Grand Banks (0.008 to 0.02 percent of 3L for no-fishing zones of 15.4 and 45 km^2, respectively; total 3L area is 152,000 km^2). The geographic distribution of fisheries in the area (Section 7.1) makes it very unlikely that catch levels will decline. Effects on potential American plaice and northern cod fisheries are difficult to predict since the timing of the recovery for these species on the Grand Banks is not certain. However, were these fisheries to return, avoiding grounds in the developed portion of White Rose should not result in any catch loss, nor should it result in higher fishing pressure on 3Lt fish outside the no-fishing zone, because these groundfish are highly mobile.

The White Rose no-fishing zone may benefit the fishery by allowing a growth refuge for a proportion of the harvested fish and shellfish populations and/or food species. Given the small size of the White Rose no-fishing zone, however, this conclusion is stronger as a statement of positive effect when considered within the greater context of cumulative oil development on the Grand Banks and is discussed in Section 7.2.2.1 below.

With respect to vessel traffic, two to three supply boats are expected to travel between White Rose and St. John's, weekly. Four tanker trips per month are expected to travel between the Project area and nearest shipping lanes (see Section 1.2.1 of the Comprehensive Study). Increased vessel traffic on the Grand Banks as a result of White Rose is not expected to interfere with fisheries. The fishing industry currently deals with many other vessels, including greatly increased numbers of vessels 65 ft or less fishing for crab on the Grand Banks. (More detail on the potential effect of vessel traffic on the fishing industry are provided under Cumulative Effects (Section 7.2.2.1)

7.2.1.2 Damage to Fishing Gear or Vessels

Damage to fishing gear or vessels might result from physical contact with White Rose vessels or installations(see also Section 7.2.2.2 for cumulative effects). Given current fisheries in 3Lt, damage is more likely to occur to gear or vessels fishing for crab. Overall, however, these types of damages are expected to occur infrequently. As of yet, there have been no reported damages as a result of the Hibernia and Terra Nova operations (D.G. Taylor, pers. comm; U. Williams, pers. comm.).

7.2.1.3 Biophysical Effects

Chapter 4 of the EIS (Part One) assesses the biophysical effects of the Project on fish, including fish and shellfish tainting and effects on fish health and productivity. The fisheries analysis looks at the effects of any such biophysical effect on fisheries catches and their value.

Negligible or minor effects to fish are predicted as a result of construction, operation and decommissioning at White Rose (Chapter 4, EIS (Part One)). Effects on fish will not be directly transferred to fisheries because additional variability will be introduced by changing fishing practices and management regimes. Therefore, effects on fisheries are anticipated to be low.

7.2.1.4 Information, Communication and Emergency Response

Increased and ongoing environmental data collection and monitoring programs for the White Rose Project will enhance understanding of the Grand Banks ecosystem and may lead to the identification of new commercial species. Again, this conclusion is stronger within the context of cumulative oil development on the Grand Banks and is discussed in Section 7.2.2.4.

7.2.1.5 Major Oil Spills

The probability of occurrence for major oil spills is extremely low. Chapter 5 of the EIS (Part One) details the probability of oil spills, large and small, over the length of the White Rose Project. Spill probability decreases with the size of spills. Spills less than 50 barrels occur frequently relative to major spills and are therefore discussed separately in both this fisheries SEIS and in the EIS (Part One). The effects of small spills are minor. Spills larger than 50 barrels are expected to occur very infrequently. Probability assessments range from 1 in 120 years for 50 to 999 barrel spills to 1 in 9,300 years for >150,000 barrel spill (details in Chapter 5, EIS (Part One)).

The most serious potential effects from major spills are loss of market or market value, loss of access to fishing grounds, damage to fishing gear and fish tainting (real or perceived). Fish mortality as a result of oil spills, although it does occur, is usually not the most critical effect of oil spills on fisheries. Several reports have been produced in recent years on the real and perceived effects of oil spills on fisheries. Locally, DeBlois et al. (1997) summarized these reports and interpreted findings with respect to conditions in Newfoundland. They noted the following:

- Biophysical Effects: Adult fish do not generally experience acute mortality during oil spills (Baker et al. 1991). Although it is evident that exposure of fish eggs and larvae will lead to some mortality, this must be weighed against the large variability and unpredictability inherent to larval fish survival. Modelling studies indicate that large numbers of eggs and larvae would have to be destroyed to affect recruitment (Reed et al. 1984; Hurlbut et al. 1991). In the post-spill years of 1990 and 1991 in Prince William Sound, adult pink salmon returned to affected rivers in high numbers, with wildstock spawners exceeding their parent year returns (Maki et al. 1995). Returns from 1990/91 would have been most affected by the 1989 oil spill.

- Tainting: There are some reports of fish tainting after oil spills but in most cases, even in the event of massive spills, descriptions of tainting are hardly more than anecdotal. Tainting of seafoods is perceived by the public, fishermen, and by regulatory authorities as an inevitable and undesirable consequence of oil discharge into the marine environment (McIntyre 1982). In spite of the fact that there is no evidence from published reports of large, or even substantial, amounts of tainting arising from oil spills, public perception of an effect can affect economic return from the fishery (Wells et al. 1993).

- Gear Damage: In addition to revenue loss due to halted harvesting, resource extraction losses include gear replacement/clean up costs. Moller et al. (1989) have summarized and discussed the vulnerability of fishing and aquaculture gear based on nearly 60 incidents over the 10 years to 1989. They give details of 30 incidents which occurred in the Far East, including the costs of clean-up and damage settlements. These authors' assessment of the sensitivity of fishing gear to oil damage is summarized in Table 7.2-2.

Table 7.2–2 Fishing Gear Sensitivity

Gear	Sensitivity to Oil
Traps and baskets (shallow water)	High
Lift nets, cast nets	Moderate
Gill nets, drift nets	Moderate
Purse seines, ring nets, beach seines	Moderate/low
Handlines, longlines, drift lines	Low
Trawls, dredges	Low

Source: Moller et al. 1989.

Oil spill trajectory model results for spills > 10,000 barrels (Section 5.8, EIS (Part One)) indicate that an oil spill occurring in the Project area would most often disperse offshore onto and to the south of the Flemish Cap. Given these dispersion patterns, fisheries that would be most disrupted include the Greenland halibut, tuna and swordfish fisheries around the Flemish Pass and the shrimp fishery on the Flemish Cap. Again, the most serious effect should be loss of market or market value, a disruption of fishing activity and potential damage to gear rather than any serious effect on fish (See Section 5.9.2.1, EIS (Part One)) for a detailed evaluation of the biophysical effects of large oil spills on fish and fish habitat).

7.2.2 Cumulative Effects

Cumulative effects on fisheries might occur as a result of the Hibernia, Terra Nova or White Rose developments, general marine transportation, seismic testing and exploration drilling. This section deals with cumulative effects with respect to loss of access to fishing grounds, damage to fishing gear or vessels, biophysical effects, and information, communication and emergency response. The effects of small chronic spills on gear and fish are covered under damage to fishing gear, as well as under biophysical effects. Large oil spills are rare accidental events and are not considered here (see Section 5.8 of the EIS (Part One) for detailed probability assessment and Section 7.3.1).

7.2.2.1 Loss of Access to Fishing Grounds

Loss of access to fishing grounds and/or increased vessel traffic on the Grand Banks will likely result in low cumulative effects on the fishery.

The total no-fishing zone for Hibernia (5 km^2), Terra Nova (13.8 km^2) (U. Williams pers. comm.) and White Rose (15.4 km^2) is approximately 34.2 km^2 or approximately 0.01 percent of the total area in 3L. In terms of lost fishing grounds, the excluded area remains a very small fraction of the total fishing area available. The distance between development sites should not impede fishing activity (Figure 7.1-21).

Further, the bulk of current fisheries catches are made either well on the landward side of oil development sites or on the shelf margin (at depths greater than 200 m) rather than in 3Lt. From 1992 to 1998, cash landings from 3Lt constituted only 0.7 percent of total Grand Banks landings (3LMNO). Cash landings in 3Lt are expected to remain low unless the groundfish fishery returns in full force. Although some groundfish fisheries will likely become important again (for example, the re-emerging yellowtail flounder fishery in 3NO), a full recovery of groundfish fisheries to 1980s levels is not certain at this time.

As discussed above, the presence of no-fishing zones can benefit fisheries by providing a growth refuge for a proportion of the harvested fish and shellfish populations and/or food species. Benefits to the fishery would accrue because increases in growth (in terms of size and numbers) in the no-fishing zone would then be transferred to surrounding areas where harvest is permitted (Shackell and Willison 1995). The benefit of fish and shellfish refuges in the White Rose, Terra Nova and Hibernia no-fishing zones is discussed in further detail in Chapter 4 of the EIS (Part One).

With respect to vessel traffic, the total number of trips per week by supply vessels supporting offshore oil operations will remain a very small fraction of total traffic on the Grand Banks. More than 20,000 fishing trips were made in 3L in 1998, in contrast to an expected 300 supply vessel trips in 2000 (A. Harvey & Co expect 25 supply vessel trips per month (300 per year) as a result of oil operations on the Grand Banks in 2000; Petro-Canada 1999). As for tankers, the total number of trips expected from the Hibernia, Terra Nova and White Rose operations to shipping lanes by year 2003/2004 is 156 per year (see Section 4.3.4.3, EIS (Part One)). This constitutes 4.8 percent of current Canadian-bound international traffic in shipping lanes around Newfoundland and 0.8 percent of fishing vessel traffic as described above. This amount of increased traffic should not interfere with normal fishing activity. In addition, Petro-Canada (1995) concluded that the proximity of the oil fields on the Grand Banks lends some benefits; vessels follow similar routes and thereby minimize potential interference with fishing vessels.

With respect to seismic testing and exploration drilling, an average of four seismic trips lasting approximately 45 days on average are expected annually, based on previous exploration frequency (1990 to 1999) (J. McIntyre, pers. comm.). Three to four exploration well projects are expected for 2000 to 2001. Seismic testing can have a negative economic effect on fisheries by halting fishing for a number of hours in the test area and by scaring fish away from fishing grounds. Although resource use conflicts between the fishing industry and seismic testing vessels have been reported (M. O'Connor, pers. comm., on conflict off the St. Pierre Bank), these should be fairly uncommon based on the frequency of seismic testing trips. For exploration drilling, Petro-Canada (1995) concluded that marine activities associated with exploration drilling programs did not substantially interfere with Grand Banks fisheries, even when fisheries and oil companies were operating at high levels.

7.2.2.2 Damage to Fishing Gear or Vessels

To date, there have been no damages reported as a result the Hibernia and Terra Nova operations (U. Williams, pers. comm.; D.G. Taylor, pers. comm.). Damage to fishing gear or vessels might nevertheless occur in the future as a result of physical contact between Hibernia, Terra Nova and White Rose vessels and installations. Small oil spills (less than 50 barrels) and materials lost from vessels, drill rigs or production facilities could damage or foul gear. In addition to fishing vessel damage or loss of gear, further economic loss might result from reduced catch following damage. Although each operator has or will have mitigation measures in place to deal with damage, there could be delays in compensation for lost or damaged gear and lost revenue if there is disagreement about which project is responsible. In such a case, the industry non-attributable damage compensation policy, currently in development, will prevail.

7.2.2.3 Biophysical Effects of Ongoing Operations

The biophysical effects of oil operations on fish are anticipated to have low cumulative effects on fisheries catches.

Chapter 4 of the EIS (Part One) provides an assessment of biophysical effects on fish, including fish and shellfish tainting and effects on fish health and productivity as a result of the Project. That Chapter of the EIS (Part One) also deals with cumulative effects in consideration of chronic oil pollution on the Grand Banks as a result of spills from other offshore operators, bilge dumping and other discharges. The EIS (Part One) identifies only negligible and minor cumulative biophysical effects on fish as a result of oil development on the Grand Banks (see Chapter 4, EIS (Part One)). As noted above, effects on fish will not be directly transferred to fisheries because additional variability will be introduced by changing fishing practices and management regimes. Therefore, effects on fisheries are anticipated to be low.

7.2.2.4 Information, Communication and Emergency Response

A positive cumulative effect is expected with respect to information, communication and emergency response as a result of oil development on the Grand Banks.

Environmental data collection and monitoring programs will enhance understanding of the Grand Banks ecosystem and may lead to the identification of new commercial species. Further, production facilities and vessels are able to provide medical services, search and rescue and advanced communications technology for emergency response to a large portion of the Grand Banks.

7.2.3 Summary of Effects

Effects, including cumulative effects of the Project on fisheries, are summarized in Table 7.2-3. In this table, an adverse effect is ranked as 1 (low magnitude) if 0 to 5 percent of Grand Banks fishers are affected; 2 (medium magnitude) if 5 to 25 percent of fishers are affected; and 3 (high magnitude) if more than 25 percent of fishers are affected. Where an adverse effect is ranked as 2 or 3, the effect of the project is considered to be significant. Mitigation measures are also briefly outlined. Mitigation is detailed in Section 7.2-4.

Table 7.2–3 Valued Environmental Component: Fisheries

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Construction, Operations, Decommissioning							
Loss of Access to Fishing Grounds	A	Discussion with Fishing Industry; Common Traffic Routes	1	3	5/6	R	2
Damage to Fishing Vessels or Gear	A	No-fishing Zone; Notification to Mariners; Reduction or Elimination of Debris; Compensation	1	5	5/1	R	1
Biophysical Impacts on Fisheries	A	See Chapter 4, EIS (Part One)	1	3	5/6	R	1
Information, Communication and Emergency Response	P	N/A	1	6	5/6	R	1

Project Activity	Positive (P) or Adverse (A) Environmental Effect	Mitigation	Evaluation Criteria for Assessing Environmental Effects				
			Magnitude	Geographic Extent	Duration/ Frequency	Reversibility	Socio-Economic Context
Malfunctions/Accidents/Unplanned Events							
Major Oil Spills*	A	Prevention; Containment; Monitoring; Recovery; Compensation	2-3	4-6	2-5/1	R	1
Past/Present/Future Projects (seismic testing, exploration drilling, marine transportation, Hibernia, Terra Nova, White Rose)							
Loss of Access to Fishing Grounds	A	Discussion with Fishing Industry; Common Traffic Routes;	1	3	5/6	R	2
Damage to Fishing Vessels or Gear	A	No-fishing Zone; Notification to Mariners; Reduction or Elimination of Debris; Compensation	1	5	5/1	R	1
Biophysical Impacts on Fisheries	A	See Chapter 4, EIS (Part One)	1	3	5/6	R	1
Information, Communication and Emergency Response	P	N/A	1	6	5/6	R	1

KEY:

Magnitude:
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1000 km²
5 = 1001-10,000 km²
6 = > 10,000 km²

Duration:
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Frequency:
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Reversibility:
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity
2 = Evidence of adverse effects

N/A = Not Applicable

* Note: Effects of major oil spills on fishing gear and on loss of access to fishing grounds can be remedied relatively quickly (often within 2 years of a spill). However, loss of market and market value for fisheries species depends on media coverage and public perception of fish taint. Because of this, impacts of major spills can extend over a larger area than the immediate geographic area affected by the spill and can extend long after oil has been removed and/or has dissipated.

7.2.4 Environmental Design, Mitigation and Optimization

7.2.4.1 Loss of Access to Fishing Grounds

To address loss of access, Husky Oil will cooperate with the fishing industry to maximize benefits to both industries and minimize effects. Compensation issues for specific loss of access and revenue will be determined on a case by case basis.

All reasonable efforts will be made to accommodate fishing activity over portions of the White Rose field that are not under development. A sequential approach to reservoir development will correspondingly allow for sequential fishing over portions of the White Rose field during exploration, pre-drilling, before production or as wells are abandoned.

Husky Oil has previously expressed a willingness to work with the fishing industry regarding vessel routing to minimize effects. Using common routes for Hibernia, Terra Nova and White Rose vessels or collaborating (where appropriate) to minimize the number of trips should reduce overall interference with the fishing industry. The fishing industry will be kept fully advized of the location and duration of Husky Oil-led seismic tests and exploration projects. Vessel traffic will be monitored. If there are problems, appropriate measures will be discussed with fisher groups.

7.2.4.2 Damage to Fishing Gear or Vessels

The no-fishing zone established at the development site is a mitigation measure to avoid damage to fishing gear and vessels, as well as to subsea facilities and the environment. Outside the no-fishing zone, and as noted above, Husky Oil will keep the fishing industry fully informed of the timing and sequence of field development and of the exact location of potential hazards.

Chapter 8 of the EIS (Part One) details procedures for reducing or eliminating debris and small spills.

A compensation program will be put in place to address claims for damages resulting from Husky Oil operations promptly.

With respect to cumulative effects, where the responsibility for damages is unclear, claims will be settled through discussion between the operators and the parties who have experienced damage. In such cases, the industry non-attributable damage compensation policy, currently in development, will prevail.

7.2.4.3 Oil Spills

Husky Oil's primary approach to reducing oil spill effects is prevention. In the event of a spill, procedures to arrest further oil release, contain, monitor and recover oil will be implemented. These procedures are detailed in Chapter 6 of the EIS (Part One).

If a major oil spill occurs, the level of injury to the fishing industry will be assessed through discussion between Husky Oil and fisher groups and will rely on the most recent baseline data and a reassessment conducted after the spill. In Part One (EIS), Husky Oil committed to submitting an oil spill-specific EEM program design to the C-NOPB for execution in the unlikely event of an oil spill.

Guidelines for the assessment of damages and compensation will be detailed in a Fisheries Compensation Program. The Program will also take into account various provincial, federal and international regulations related to major oil spills (see Section 7.3.2).

7.3 INTEGRATED RESIDUAL ENVIRONMENTAL EFFECTS

7.3.1 Residual Environmental Effects

Likely environmental effects on fisheries resulting from White Rose are identified in Sections 7.2.1 and 7.2.2. Mitigation and optimization measures that will reduce effect on fisheries are identified in Section 7.2.4. This section, Residual Environmental Effects, deals with effect size after mitigation and optimization.

For the most part, potential effects on fisheries are small and can be further decreased by the implementation of various mitigation measures. The majority of mitigations involve discussion and collaboration between Husky Oil and the fishing industry (see Table 7.2-3). Residual environmental effects, after mitigation, by Project phase are summarized in Table 7.3-1. For the most part, residual effects are not significant. However, the predicted effect of large oil spills on the fishery is significant. It should be noted that the predicted effect of a large oil spill on fish and fish habitat (Part One, Section 5.9) is not significant. It is the fish that is the renewable resource, not the harvesting of the fish, therefore, the fishery will be able to meet the future needs of resource users.

Table 7.3–1 Residual Environmental Effects Summary Matrix

Valued Environmental Component: Fisheries				
Phase	Residual Environmental Effects Rating, Including Cumulative Environmental Effects[1]	Level of Confidence	Likelihood	
			Probability of Occurrence	Scientific Certainty
Seismic testing	NS	3	1	2
Construction	NS	3	1	2
Operations	NS	3	1	2
Decommissioning	NS	3	1	2
Malfunctions, Accidents and Unplanned Events (Major Oil Spills)	S	3	1	3
Project Overall	NS	3	1	2

Key:

Residual Environmental Effect Rating:

S = Significant Adverse Environmental Effect
NS= Not-significant Adverse Environmental Effect
P = Positive Environmental Effect

Level of Confidence

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability of Occurrence: based on professional judgement

1 = Low Probability of Occurrence
2 = Medium Probability of Occurrence
3 = High Probability of Occurrence

Scientific Certainty: based on scientific information and statistical analysis or professional judgement

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

[1] As determined in consideration of established residual environmental effects rating criteria.

7.3.2 Monitoring and Follow Up

A Fisheries Compensation Program will be put in place and will take into account regulations and guidelines relevant to fisheries including, but not necessarily limited to: the *Canada-Newfoundland Atlantic Accord Implementation Act*, the *Canada Shipping Act*, the *Canadian Petroleum Act*, as well as guidelines and regulations contained in various international agreements.

Husky Oil will undertake a review of previous damages incurred by the fishing industry from offshore oil operations or transport in order to establish proper compensation measures.

An update of fisheries baseline in five years time could be considered as part of an EEM program due to concerns about changing fisheries on the Grand Banks. In the interim, Husky Oil will remain open to discussions with fishers on new fisheries that may be affected by White Rose.

8 CONCLUSION

This assessment of the socio-economic effects of the White Rose oilfield development project indicates that it will have a range of positive consequences for Newfoundland and its citizens, families and communities. The potential adverse effects are minor and non-significant. However, if there was a major oil spill, which has a very low probability of occurrence (that is, an unlikely event), a significant adverse effect is predicted on the commercial fishery.

The main positive effects relate to its effect on the economy. As is discussed previously, White Rose will create large amounts of employment and business in the province during all phases of activity. This will, in turn, create spin-off employment and business, as well as create new revenues for government through personal, business and property taxes. Municipal government will also benefit through increased user pay for the use of recreational and other infrastructure and services. White Rose will also be subject to the Government of Newfoundland's generic royalty regime, resulting in major direct government revenues.

White Rose will be the latest in what promises to be a series of further oilfield development projects. As such, it will build on, and further contribute to, the development of a multi-phase offshore oil industry in Newfoundland. The development of this industry both reduces industry costs in Newfoundland, thereby encouraging additional projects and maximizing local benefits, and contributes to the likelihood of Newfoundland individuals and companies being successful in the international oil industry. In particular, White Rose will see Newfoundland expanding its capabilities in some of the industry's main growth areas, including floating production systems, sub-sea completions and directional drilling. Expertise and capabilities in these areas are highly transportable, providing major export opportunities for Newfoundlanders and Labradorians and for local companies.

This SEIS also examines the social effects of White Rose on local people, families and communities. While these are issues that caused considerable concern in the 1980s, subsequent experience is that, given appropriate management initiatives, these effects are very minor and largely positive. Experience with the Hibernia construction project, Hibernia production and Terra Nova construction (to date) has led White Rose public consultation participants, whether key informants or members of the general public, to be generally sanguine about the social effects on individuals, families and communities.

Whether in St. John's, Arnold's Cove, Clarenville, Marystown, Placentia, Gander or Corner Brook, White Rose is seen as 'just' another oil industry project that will use existing industrial and commercial facilities and infrastructure. It is also recognized that any economic development will inevitably have minor negative effects, but that the balance of benefits to costs hugely favours the former, and that the resulting increase in government revenues can and should go to addressing any minor negative effects.

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GLOSSARY

This glossary includes terms found in the Comprehensive Study, including Parts One and Two.

10^3. Acronym for thousand.

10^6. Acronym for million.

10^9. Acronym for billion.

1G. First generation [model].

2G. Second generation [model].

3G. Third Generation [model].

abandonment. The decommissioning of facilities and removal of offshore structures following exhaustion of reserves.

abiotic. Non-biological; a process not mediated or resulting from the activity of organisms. Ocean currents and weather are examples of abiotic processes.

accretion. Growth by organic enlargement; growing of separate things into one.

active ice management. A term that describes any action taken to influence an iceberg's drift.

ADCP. Acronym for Acoustic Doppler-Current Profiling.

ADDS. Acronym for Aerial Displacement Delivery System.

advection. The process of, or referring to the transport of one fluid mass (air, water) by the movement of another.

aerobic. A process requiring the presence of air or oxygen.

AERP. Acronym for Alert and Emergency Response Plan.

AES. Acronym for Atmospheric Environment Service (a branch of Environment Canada).

AHH. Abbreviation for aryl hydrocarbon hydroxylase.

airborne reconnaissance. Reconnaissance performed by a specialised remote sensing aircraft.

alcids. A group of shorebirds, predominantly of northern coasts, including auks, puffins, murres and puillemots.

anadromous. Used to describe fish that spawn in fresh water after spending most of their life in the sea.

anaerobic. Not requiring the presence of oxygen.

anomaly. A geological feature, especially in the subsurface, distinguished by geological, geophysical or geochemical means, which is different from the general surroundings and is often of potential economic value (for example, a magnetic anomaly).

ANSI. Acronym for American National Standards Institute.

anthropogenic. Derived or resulting from human activity.

anticline. A fold, generally convex upward, whose core contains the stratigraphically oldest rocks.

anticyclone. An atmospheric pressure distribution in which there is a high central pressure related to the surroundings. Resulting weather is usually quiet and settled.

APEGN. Acronym for Association of Professional Engineers and Geoscientists of Newfoundland

API. Acronym for American Petroleum Institute.

artificial reef. An underwater artificial structure that provides habitat similar to that provided by a natural reef.

artificial reef effect. The effect generated by the placement of an undersea structure in an area where previously there were no similar habitats. Benthic organisms colonize the structure and, subsequently, fish and other organisms are attracted to it in search of food.

astronomical tides. The alternate rise and fall of the surface of the oceans, seas, and the bays, rivers. Etc., connected with them, caused by the gravitational attraction of the sun and moon.

Avalon Channel. A deep-water channel just off the Avalon Peninsula created by a branch of the Labrador Current.

Avalon Formation. A particular rock deposit that formed approximately 110 million years ago in the Cretaceous period. It is the reservoir rock of the White Rose South oil pool and the principal reservoir rock of the White Rose oilfield.

avg. Abbreviation for average.

ballast water. Water carried in the tanks on a vessel (for example, tanker) to maintain sea-going stability.

barite. A mineral (barium sulphate); used as a weighting material for drilling because of its high specific gravity.

bathymetry. The measurement of depths of water in oceans, seas and lakes; also the information derived from such measurements.

bbl. Abbreviation for barrel.

BCD. Acronym for Bitter Crab Disease.

bedrock. A general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.

benthos. Organisms living on, in or attached to the sea bottom; includes both animals and plants.

bergy bit. A piece of floating glacier having a sail greater than 1.5 m but less than 5 m and a water plane area greater than 20 m^2 but less than 300 m^2. Size approximates that of a small house and mass is between 120 and 5,400 t.

best value. A blend of total cost, quality, technical suitability, delivery and continuity of supply and service.

BHT. Acronym for bottomhole temperature.

BIO. Acronym for Bedford Institute of Oceanography.

biocide. A chemical agent that destroys bacteria.

biodegradable. Refers to a substance that can be broken down by micro-organisms.

biodegradation. The biological conversion of organic material to inorganic nutrients.

biofouling. The encrustation of submerged structures by barnacles and molluscs, seaweeds and other marine life; also known as marine fouling.

biological oxygen demand (BOD). The amount of dissolved oxygen required to meet the metabolic needs of anaerobic micro-organisms in water rich in organic matter such as sewage.

biomass. The amount of living matter of a specified type given as a concentration per unit area or volume.

biota. The flora and fauna of a region.

bioturbation. The churning and stirring of a sediment by organisms.

bloom. Rapid growth of a population of planktonic organisms.

BOP. Acronym for blowout preventer.

BOPD. Abbreviation for barrels of oil per day.

boreal. Northern.

boulder. A rounded rock fragment greater than 256 mm in diameter.

BS&W. Acronym for basic sediment and water.

by-catch. Organisms that are caught commercially but are not the target species (for example, haddock is often a by-catch of the cod fishery).

calcareous. Containing calcium carbonate.

calcite. A mineral with the composition $CaCO_3$; the principal constituent of limestone.

calved/calving. Icebergs broken off from a glacier that reaches the sea.

CAO. Acronym for Client Assistance Officer.

CAPP. Acronym for Canadian Association of Petroleum Producers.

CASP. Acronym for Canadian Atlantic Storms Program.

CCG. Acronym for Canadian Coast Guard.

C-CORE. Acronym for Centre for Cold Ocean Resources Engineering.

CCRS. Acronym for Canadian Centre for Remote Sensing.

CCSD. Acronym for Consolidated Census Subdivision.

CEAA. Acronym for *Canadian Environmental Assessment Act*.

CERT. Acronym for Corporate Emergency Response Team.

chemical oxygen demand (COD). The amount of dissolved oxygen required to allow the abiotic oxidation of chemical compounds.

chlorophyll. A green pigment found in all algae and higher plants. Responsible for light capture in photosynthesis.

Christmas (Xmas) Tree. Arrangement of valves and fittings attached to the tubing head to control flow and provide access to the tubing string.

CIS. Acronym for Canada Ice Sevices.

climax. A community that has reached a steady-state under a particular set of environmental conditions.

cluster. Wells grouped together to minimize infield flowlines.

CMA. Acronym for Census Metropolitan Area. The main labour market of an urbanized core (or continually built-up area) having 100,000 or more population. CMAs are created by Statistics Canada and are usually known by the name of the urban area forming this urbanized core. CMAs comprise municipalities completely or partly inside the urbanized core; and other municipalities where at least 40 percent of the employed labour force living in the municipality works in the urbanized core, or at least 25 percent of the employed labour force working in the municipality lives in the urbanized core.

CMG. Acronym for course made good.

CMHC. Acronym for Canada Mortgage and Housing Corporation.

CNA. Acronym for College of the North Atlantic.

C-NOPB. Acronym for Canada-Newfoundland Offshore Petroleum Board.

CO_2. Chemical formula for carbon dioxide.

COADS. Acronym for Comprehensive Ocean-Atmosphere Data Set.

cobble. A rounded rock fragment between 64 and 256 mm in diameter.

compaction (sediment). Reduction in bulk volume, or thickness of, or the pore space within a body of sediments in response to the increasing weight of overlying material that is continually being deposited or to the pressures resulting from earth movements within the crust. It is expressed as a decrease in porosity brought about by a tighter packing of the sediment particles.

complex. A large geological structural feature composed of several smaller structural features. In this case, the complex refers to the White Rose salt dome and adjacent collapse features, including many individual fault blocks.

condensate. Liquid hydrocarbons that are produced with natural gas and that separate from the gas as a result of decreases in temperature and pressure.

Continental Shelf. Gently sloping, shallowly submerged marginal zone of the continents extending from the shore to an abrupt increase in bottom inclination; greatest average depth less than 183 m, slope generally less than 1 to 1000, local relief less than 18.3 m, width ranging from very narrow to more than 320 km.

Continental Slope. Continuously sloping portion of the continental margin with gradient of more than 1 to 40, beginning at the outer edge of the Continental Shelf and bounded on the outside by a rather abrupt decrease in slope where the continental rise begins at depths raging from approximately 1,400 and 3,000 m.

core. A cylindrical boring of rock from which composition and stratification may be determined.

COSEWIC. Committee or Status of Endagered Wildlife in Canada.

CPA. Acronym for closest point of approach.

CPUE. Acronym for catch per unit area.

Cretaceous. A period of geological time approximately 131 to 65 million years ago. Dinosaurs and other reptiles thrived in the early Cretaceous but by the end of this period, dinosaurs and many of the reptiles had become extinct.

crude oil. Unrefined petroleum.

crustaceans. Invertebrate animals, such as lobster, shrimp, crab, copepods and amphipods, with at least five pairs of jointed legs.

CSA. Acronym for Concept Safety Assessment.

CTD. Acronym for conductivity-temperature-depth.

current shear. A tangent or plane of contact where two opposing currents collide and are subsequently driven away from each other.

cuttings. Chips and small fragments of rock that are brought to the surface by the drilling mud as it circulates.

cuvette. A small depositional area, smaller than a basin or a sub-basin.

cyclogenesis. The initiation of cyclonic circulation, or strengthening around an existing depression or cyclone.

cyclone. A circular or nearly circular area of low atmospheric pressure around which the winds blow counterclockwise in the Northern Hemisphere and clockwise in the south. It may cause precipitation and cloudiness over many thousands of square kilometres.
CYT. Acronym for cunner/yellowtail flounder.

d. Abbreviation for day.

Davis Strait. The area of water between southern Baffin Island and southern Greenland.

dB. The abbreviation for decibel.

deadweight. The maximum design weight of cargo, crew and effects for a ship (the "payload").

deflect. To move a piece of ice off its track by towing, propwashing or use of a water cannon

dehydration. Removal of water from a hydrocarbon fluid.

delineation wells. Wells drilled after the initial exploration well to give a better understanding of the extent and performance of the reservoir**.**

deltaic. Pertaining to, or like a delta.

demersal. Referring to animals, usually fish, associated with, but not living on, the sea bottom.

depuration. Holding bivalve molluscs in clean seawater to allow any undigested food to be flushed out to ensure no comtamination from food during body burden analyses.

detection. Locating or finding an object.

detrital. Particles occurring in sedimentary rocks that were derived from pre-existing igneous, sedimentary or metamorphic rocks, or other pre-existing material.

detritus. Dead or decaying organic matter and associated micro-organisms that are responsible for its decomposition.

Development (White Rose Oilfield Development). "Development" refers to all phases of the project, from the decision to go ahead with construction through to abandonment of the field.

Development Application. The official title of the documentation to be submitted to the Canada-Newfoundland Offshore Petroleum Board in support of the White Rose oilfield development. The Development Application includes: Project Summary; Canada-Newfoundland benefits Plan (Volume 1); Development Plan (Volume 2): Environmental Impact Statement (Volume 3); Socio-Economic Impact Statement (Volume 4); and Concept Safety Analysis/Safety Plan (Volume 5).

DFO. Acronym for federal Department of Fisheries and Oceans.

diatoms. Microscopic algae characterized by “pill-box like” cell walls containing silica.

diel. twice daily.

dinoflagellate. A chiefly marine one-celled organism with resemblances to both plants and animals. Hard parts preserved as microfossils are important for dating and correlating Mesozoic and Cenozoic deposits.

direct effects. The expenditure, income and employment created by offshore oil and gas-related construction and operation.

direct employment. Individuals involved in the design, construction, installation, operation and maintenance of all main field components during the development and production stages.

discovery well. An exploratory well that encounters a new and previously untapped petroleum deposit; a successful wildcat well.

distal. Far from the point of attachment or origin.

DND. Acronym for Department of National Defence.

DNV. Acronym for Det Norske Veritas.

DO. Abbreviation for dissolved oxygen.

DOC. Abbreviation for dissolved organic carbon.

downdip. A direction towards a lower elevation from a given point on a structure or surface.

draft. The amount of an iceberg under the surface of the ocean (about 7/8ths).
drift. The movement of any type of ice. Composed of drift speed and drift direction.

drift trend. The movement of ice over time.

drill centre. Location at which a group of wells is drilled.

drilling mud. A circulating fluid used in drilling wells. Usually contains weighting agents, viscosifiers and fluid loss additives. Can be water or synthetic based.

drilling platform. An offshore structure from which a number of wells are drilled. The legs of the platform are anchored to the seabed and the platform is built on a large-diameter pipe frame.

drilling rig. A ship-shaped or semi-submersible vessel, or a jackup platform, with equipment suitable for offshore drilling.

DSV. Acronym for Diving Support Vessel.

DWT. Acronym for dead weight tonnage.

EAT. Acronym for Emergency Action Teams.

ECERT. Acronym for East Coast Emergency Response Team

ECETOC. Acronym for European Chemical Industry Ecology and Toxicology Centre.

echinoderms. Invertebrate animals with radial symmetry and high carbonate content; includes starfish, brittlestars, sea urchins, sand dollars and sea cucumbers.

ECM. Acronym for environmental compliance monitoring.

ecosystem. The complex of a community and its environment functioning as an ecological unit in nature.

ECRC. Acronym for Eastern Canada Response Corporation.

EEM. Acronym for environmental effects monitoring.

effect area. A term used in environmental impact statements to define that geographic area in which the human and natural environments may be affected, positively or negatively, by the establishment of a major development project.

effect. An observable and measurable response of a population, individual or a biotic factor to an external source of disturbance.

EIS. Acronym for Environmental Impact Statement.

endangered. Descriptive of a species that is in danger of extinction within all or part of its range (the region to which it is native).

Environmental Impact Statement (EIS). A document that attempts to predict the effects of a major development might have on the human and natural environments of a given geographic area. An EIS is prepared to enable industry, government and the public to consider the environmental costs and benefits of a development project. Based on the information contained in the EIS, decisions can be made on whether to proceed with the development project.

epibenthos. Plants or animals that live on the sea bottom. Some of the animals are not attached, but crawl about.

epifauna. Benthic animals living attached to or crawling over the bottom of the sea.

EPP. Acronym for environmental protection plan.

EPT. Acronym for electromagnetic propagation.

ESD. Acronym for emergency shut down.

ESDV. Acronym for emergency shut down valve.

ESRF. Acronym for Environmental Studies Revolving Fund.

estuary. That area of a coastal embayment that is under the influence of both fresh water and seawater.

ethane. A simple hydrocarbon (C_2H_6) composed of two carbon atoms and six hydrogen atoms; a gas at atmospheric conditions.

euphausiid. Small shrimp-like zooplankton commonly known as krill.

euphotic zone. The upper layers of the water column down to the limits of effective light penetration for photosynthesis.

euxinic. Pertaining to an environment of restricted circulation and stagnant or anerobic conditions; anoxic.

exploration well. A well drilled to find an oil- or gas-bearing formation.

FAO. Acronym for a) Financial Assistance Officer and b) Food and Agriculture Organization.

fast ice. Ice attached to land or a permanent ice shelf excluding grounded ice or ice of land origin.

fault. A fracture or fracture zone along which there has been displacement of the sides relative to each other parallel to the fracture. The displacement may be a few millimetres or many kilometres.

Fault Block Traps. A hydrocarbon trap created by differential movement along faults that fragment the reservoir into one of several structural compartments.

fecundity. Fertility.

FEED. Acronym for front end engineering and design.

filter feeder. Animals that strain suspended food particles from the surrounding water.

First Oil. Milestone achieved when the first shuttle tanker has been filled with oil from the White Rose production system and the shuttle tanker disconnects from the offloading system. The entire production system is handed over to operations personnel at this point. This is the first quantity of oil to be delivered from the reservoir through the complete production and offloading system, including fiscal metering.

flare. An arrangement of piping and burners used to dispose of surplus combustible vapours (by burning).

flaring. Disposal of surplus combustible vapours by burning at the discharge of the flare tower.

flatfish. Fish with a flattened body and both eyes on one side of the head. Includes plaice, flounder and halibut.

flegde. To raise a young bird until it is able to fly.

floating production system. A monohull or semi-submersible vessel with equipment suitable for producing hydrocarbons.

floe. The surface area of individual pieces of pack ice.

flowline. Pipe which conveys crude oil from the well to the riser, or mud, water or gas from the riser to the well.

fluvial. Of or pertaining to a river.

flux. A flow, as icebergs through an area.

foraminifer. Any protozoan belonging to the subclass Sarcodina, order Foraminifera; unicellular animals mostly of microscopic size that secrete tents, composed of calcium carbonate, or build them of cemented sedimentary grains, consisting of one to many chambers arranged in a great variety of ways. Most foraminifers are marine, but freshwater forms are known.

formation water. Water present in a water-bearing formation under natural conditions, as opposed to introduced fluids, such as drilling mud.

FPDSO. Acronym for floating production, drilling, storage and offloading facility.

FPF. Acronym for floating production facility.

FPI. Acronym for Fishery Products International.

FPSO. Acronym for floating production system. A monohull or semisubmersible vessel with equipment suitable for producing hydrocarbons.

FPU. Acronym for floating production unit.

front. A slope transition zone between two water or air masses of differing density and temperature.

frontal zone. The three-dimensional zone or layer of large horizontal density gradient, bounded by frontal surfaces and surface front.

FSU. Acronym for floating storage unit.

FWS. Acronym for US Fish and Wildlife Service.
gas lift. Gas injected into the well to reduce the hydrostatic pressure on the fluid column and hence enhance flow.

GBS. Acronym for gravity based structure.

GDP. Acronym for Gross Domestic Product.

geology. The study of the structure, origin, history and development of the Earth.

geostrophic. Pertaining to deflecting force resulting from the Earth's rotation.

GESAMP. Acronym for Group of Experts on the Scientific Aspects of Marine Pollution.

glacial ice. Ice formed in a glacier.

glacier. A huge mass of ice made from compacted snow moving over land.

glaciomarine. Marine sediments that contain glacial material.

glory hole. Hole, excavated in the seabed, in which wellhead facilities are placed for protection from iceberg scour.

GMDSS. Acronym for Global Marine Distress Signalling System.

GOR. Acronym for gas-oil ratio.

GPS. Acronym for Global Positioning Systems.

grain. A general term for sedimentary particles of all sizes (from clay to boulders), as used in the expressions "grain size," "fine-grained" and "coarse-grained".

groundfish fishery. Includes all bottom-feeding fish such as cod, haddock, redfish, halibut, flatfish, turbot, pollack, hake, lumpfish and wolffish.

groundfish. Species of fish that are collected by bottom gear (trawls) (for example, cod, haddock and flounder).

GROW. Acronym for Global Reanalysis of Ocean Waves.

growler. A very small piece of glacial ice calved from an iceberg.

gyre. Circular movement of water masses.

h. Abbreviation for hour.

habitat. The place where an animal or plant lives, often characterized by some physical condition (for example, seabed habitat).

HAZID. Acronym for Hazard Identification.

HC. Abbreviation for Height Crest.

heterotrophs. Organisms that receive nourishment by ingesting and breaking down organic matter from the surrounding water.

HF. Acronym for high frequency radio.

HM. Abbreviation Maximum Individual Waveheight.

HMDC. Acronym for Hibernia Management and Development Company.

housing starts. A start is defined when the footing of a housing unit has been installed, that is when the concrete has been poured for the whole of the footing around the structure.

HS&E. Acronym for Health, Safety and Environment.

hurricane. A tropical cyclone with wind speeds over 118 kph, usually accompanied by rain, thunder and lightning.

Husky Oil. Abbreviation for Husky Oil Operations Limited.

hydrography. The science of the waters of the Earth's surface, particularly with reference to their physical features, position, volume, etc., and the preparation of charts of seas, lakes, rivers, contours of the seabed, shallows, deeps, current, etc.

hydroids. Typical colonial polyps with variously branched bushy or feathery growths. Each polyp has a crown of tentacles around the mouth.

hyperbenthic. Benthic or bottom organisms that spend part of their time on the water column for feeding of reproduction.

Hz. Abbreviation for hertz; unit of sound frequency equal to one cycle per second.

ICCAT. Acronym for International Commission for the Conservation of Atlantic Tunas.

ice breaking. Using a vessel to break up pack ice floes.

ice management. A term to describe any action to detect, collect information, monitor or track ice.

ice regime. Amount and extent of sea ice characteristic of a geographic area.

iceberg draft. Maximum depth of iceberg under water.

iceberg scour. Seafloor trench caused by the ploughing motion of an iceberg grounding on the ocean floor.

ice-infested waters. Parts of the ocean where ice is present.

ichnology. The study of fossil tracks, trails, burrows, tubes and borings resulting from the life activities of animals, which took place on or in soft sediment.

ichthyoplankton. Collective term for fish eggs and larvae when planktonic.

ICS. Acronym for Incident Command System.

IDNS. Acronym for Ice Data Network System.

IIP. Acronym for International Ice Patrol.

IMO. Acronym for International Maritime Organization.

indirect employment. Individuals employed in the offsite manufacture and supply of material inputs required by oil-related activities.

inertial currents. Wind-driven currents that oscillate in horizontal circular paths.

inertial period. The amount of time required for an inertial current to complete a full circle.

infilling. A process of deposition by which sediment falls or is washed into depressions, cracks or holes, as the filling in of crevasses upon the melting of glacial ice.

injection water. Water pumped into the formation to maintain reservoir pressure (secondary recovery technique); offshore, injection water is filtered seawater treated with biocides, oxygen scavenger and scale inhibitor.

in-migration. In this document, the movement of population into an area from elsewhere, including other adjacent areas, other part of the province, elsewhere in Canada or from other countries.

inshore fishery. Refers to fishing using vessels 35 feet and under in length.

Interannual. Year-to-year.

Isopods. A group of crustaceans including wood lice and sow bugs.

Jurassic. A period of geologic time from approximately 210 to 131 million years ago. Older plant groups continued to decline and newer forms continued to spread, dinosaurs were growing in size and becoming specialized for varied ways of life, and marsupial mammals and the first birds appeared.

juvenile. Fish past the larval stage of development, but not yet large enough to be caught in the commercial fishery (for example, cod remain juveniles for approximately four years).

killing the well. Causing the flow from the well to come to a complete stop.

kleptoparasite. A bird that steals food from other birds to feed its young; includes jaegars and skuas.

km. Abbreviation for kilometre.

km^2. Abbreviation for square kilometre.

kPa. Abbreviation for kiloPascal.

kts. Abbreviation for knots.

kV. Abbreviation for kilovolts.

kW. Abbreviation for kilowatts.

L. Abbreviation for litre.

Labrador Current. Cold water current originating in Baffin Bay and flowing along the Labrador coast and around the Grand Banks.

larva. The first immature phases of many animals after hatching of eggs and before assuming the adult form and habitat.

LC_{50}. Acronym for the concentration of a toxicant necessary to kill 50% of the test organisms in a standard time period.

LCM. Acronym for Loss Control Management, Husky Oil's loss management framework.

LCVA. Acronym for Life Cycle Values Assessment.

LFA. Acronym for Lobster Fishing Area.

lithology. The physical character of a rock.

logging. A systematic recording of data from the driller's log, mud log, electrical well log or radioactivity log.

Lower Cretaceous. The older strata of the Cretaceous period, which ranges from 65 million years before present to 131 million years before present.

LP. Acronym for low pressure.

m. Abbreviation for a) metre or b) earthquake magnitude.

m^2 . Abbreviation for square metre.

m^3. Abbreviation for cubic metre.
macrophytes. Macroscopic (large) attached aquatic plants.

management zone. A geographic radius around the platform set up for purposes such as ice management.

manifold. Device which routes the flow from several wells into organized flow streams.

MANMAR. Acronym for Manual of Marine Weather Observing.

MARPOL. Acronym for International Convention for the Prevention of Pollution from Ships.

matrix. The natural material, generally argillaceous, in which any metal, fossil, pebble, crystal, etc., is embedded; interstitial detrital argillaceous material in sandstones.

mBRT. Acronym for metres below rotary table.

mD. The abbreviation for milliDarcy.

mean. The average of a distribution of numbers.

median. The number that divides a distribution exactly in half.

MEDS. Acronym for Canadian Marine Environment Data Service.

megaripple. A large, gentle, ripple-like feature composed of sand in subaqueous environments having wavelength greater than 1 m or a ripple height greater than 10 cm. Wavelengths reach 100 m and amplitude approximately 0.5m; may be formed by tidal currents.

Mesozoic. An era of geologic time, from the end of the Paleozoic to the beginning of the Cenozoic, or from approximately 225 to 65 million years ago.

MFPSV. Acronym for Multifunctional Platform Support Vessel.

mg. Abbreviation for milligram.

microbiota, micro-organisms. Microscopic organisms, including animals, plants, bacteria, yeasts, fungi, etc., which are primarily single-celled, although some colonial forms and multi-celled organisms are included. Individuals range in size from approximately 0.0001 to 0.5 mm in diameter.

migration. In seismic processing, plotting of dipping reflections in their true spatial positions.

min. Abbreviation for minute.

mitigating (mitigative) measure. A procedure designed to reduce or negate the possible harmful effects of a substance or process on a species, habitat or environment.

MLW. Abbreviation for mean low water.

mm. Abbreviation for millimetre.

MMS. Acronym for US Minerals Management Service.

MODU. Acronym for mobile offshore drilling unit.

mol. Abbreviation for molecular weight.

mollusc. An animal possessing an external or vestigial calcium carbonate shell; including clams, snails and squid.

monitoring. Using either radar or a standby vessel to track a piece of ice.

monohull. A ship-shaped vessel.

MPa. Abbreviation for megapascal.

MPE. Acronym for Marine Pelagic Environment.

MRSC. Acronym for Marine Rescue Sub Ccntre.

MSL. Acronym for Mean Sea Level. The mean surface water level determined by averaging heights at all stages of the tide over a 19-year period. Mean sea level is usually determined from hourly height readings measured from a fixed, predetermined reference level.

mSS. Abbreviation for metres subsea.

mud pulse telemetry directional tools. These tools (commonly referred to as MWD) measure and transmit to surface all the drill bit orientation information required to guide the directional drilling operations. The tool transmits the information up the drill pipe by creating coded pressure pulses in the mud column. The pulses are then decoded by surface computers, which then present the information to drilling personnel.

multiplier. The relationship between the change in income and the change in expenditure that causes the change in income. A measure of the increased economic activity generated by an investment. It is composed of two effects: indirect and induced. Indirect effects from construction and operation of offshore platforms, for example, arise from supplying material inputs like steel. This may increase the output of the steel industry, which in turn would result in greater production of iron ore and coal. Induced effects result from the spending and re-spending of workers' incomes, which come about either directly or indirectly as a result, for example, of offshore platform construction and operation.

MUSIC. Acronym for Memorial University Seismic Interpretation Centre.

MW. Abbreviation for megawatt.

MWD. Acronym for measurement while drilling.

N_2. Abbreviation for nitrogen.

NACE. Acronym for National Association of Corrosion Engineers.

NAFO. Acronym for Northwest Atlantic Fisheries Organization.

NALTWG. Acronym for North Atlantic Leatherback Turtle Working Group.

NCAR. Acronym for US National Centre for Atmospheric Research.

NCEP. Acronym for US National Centres for Environmental Protection.

NEB. Acronym for National Energy Board.

neckton. Free-swimming marine organisms ranging in length from 10 to 200 mm; they include both invertebrate and vertebrate animals.

neritic. The zone of the ocean inshore from the edge of the Continental Shelf, including coastal bays and inlets and the Continental Shelf.

neuston. Planktonic organisms living in or near the surface film at the surface of the sea.

NGL. Acronym for natural gas liquids; liquid hydrocarbons produced with natural gas that can be separated from the gas by changes in temperature and pressure (includes ethane, propane, butane and pentane).

NLHC. Acronym for Newfoundland and Labrador Housing Corporation.

NMFS. Acronym for US National Marine Fisheries Service.

NOIA. Acronym for Newfoundland Ocean Industries Association.

NPV. Acronym for net present value.

nursery area. An area that supports fish during their first year of life.

OCMS. Acronym for Offshore Chemical Management System.

OCS. Acronym for Outer Continental Shelf.

ODGP. Acronym for Gulf of Mexico Ocean Data Gathering Program.

OERT. Acronym for Offshore Emergency Response Team.

offal. Refuse, garbage.

offshore fishery. Refers to fishing using vessels 100 feet and over in length.

OIM. Acronym for offshore installation manager.

oleoclasts. Bacteria that have the ability to degrade hydrocarbons.

OLS. Acronym for offshore loading system.

on-shore/at-shore hook-op. The installation, testing and commissioning of topsides modules at a designated hook-up site.

OOIP. Acronym for original oil in place.

Operations Phase. The period following First Oil until cessation of all oil production from the White Rose oilfield. Includes post First Oil development drilling, offshore installation activities, production, operations, maintenance, well abandonment, decommissioning and removal from the White Rose oilfield of all facilities, equipment and vessels used in the production system.

Operator. When capitalized in this document, refers to Husky Oil.

OPRC. International Convention on Oil Preparedness Response and Co-Operation, 1990.

OSC. Acronym for On-Scene Commander.

OSRL. Acronym for Oil Spill Response Limited.

OTTF. Acronym for Offshore Technology Transfer Fund.

ovoviviparous. Producing eggs that are hatched within the body so that the young are born alive but without placental attachment; as certain reptiles and fishes, etc.

Owner/Operator. When capitalized in this document, refers to Husky Oil.

OWTG. Acronym for Offshore Waste Treatment Guidelines.

P&S. Acronym for plugged and suspended.

pa. Abbreviation for pascal.

pack ice. Any area of sea ice, except fast ice, composed of a heterogeneous mixture of ice of varying ages and sizes, and formed by packing together of pieces of floating ice.

pack ice age. The stage of development of the ice.

pack ice concentration. The area of water covered by ice. Described in tenths.

PAH. Acronym for polycyclic aromatic hydrocarbons.

PAL. Acronym for Provincial Airlines Ltd.

paleo. Ancient, old.

paleogeography. The geography of ancient times or of a particular past geological epoch.

paleontology. A science dealing with the life of past geological periods as known from fossil remains.

palynology. A branch of science dealing with the study of pollen, spores and dinoflagellates, either living or fossil.

PAU. Acronym for pre-assembled unit.

pebbles. Smooth rounded stones ranging from 2 to 64 mm in diameter.

pelagic. Living or feeding in the water column.

PERD. Acronym for Panel on Energy Research and Development.

perforating. Piercing the casing wall and cement sheath to provide a flow path through which formation fluids may enter the wellbore. Perforating is done with shaped explosive charges.

permeability. The capacity of a rock to transmit a fluid. Degree of permeability depends upon the size and shape of the pores, the size and shape of their connections, and the extent of the latter. It is measured by the rate at which a fluid of standard viscosity can move a given distance through a given interval of time.

petroleum. Oil and natural gas.

photosynthesis. The use of sunlight by plants to combine water and carbon dioxide into simple sugars.

physiography. The description and origin of landforms.

phytoplankton. Planktonic (that is, floating or swimming) photosynthesizing organisms that are mostly single-celled, although some are colonial; some are capable of swimming, while others are incapable of independent motion.

pig. Device used for pumping through a pipeline to clean the walls or remove an obstruction.

plankton. Organisms living in water that are not capable of swimming vigorously enough to move independently of water movements.

PLL. Acronym for probable loss of life.

plume. A trail of oil or gas.

PM. Acronym for particulate matter.

POB. Acronym for Persons on Board.

polychaete. A marine worm with true body segments and hard spines.

pore pressure. The pressure of the interstitial fluids in a rock formation.

porosity. The volume of the pore space expressed as a percentage of the total volume of the rock mass.

pour point. Lowest temperature at which a substance flows under specified conditions.

PPE. Acronym for personal protective equipment.

ppb. Abbreviation for parts per billion.

ppm. Abbreviation for parts per million.

ppt. Abbreviation for parts per thousand (I).

Pre-Engineering. All of the engineering work undertaken before the Project Phase to determine the preferred production system for White Rose.

pressure gradient. The rate of pressure increase with depth.

primary production. Carbon fixation during photosynthesis; includes phytoplankton.

Probability of Detection (POD). The likelihood of detecting an object by radar, given its RCS and the weather conditions. Expressed in percent.

produced sand. Sand produced with oil and gas.

produced water. Water from the producing formation that comes to surface with the oil and gas. It separates from the oil and gas at atmospheric temperatures and pressure.

productivity. The rate of production of new biomass by populations of organisms.

progradation (or prograding). The building forward or outward toward the sea of a shoreline or coastline (as of a beach, delta or fan) by nearshore deposition of river-borne sediments or by continuous accumulation of beach material thrown up by waves or moved by longshore drift.

Project Phase. The period beginning with regulatory approval of the Development Application and the Proponents' authorization to execute the White Rose oilfield development, up to the production and offloading of First Oil. Includes detail engineering, procurement, construction, commissioning, installation and development drilling up to First Oil. Does not include development drilling after First Oil.

protozoa. A group of single-celled animals.

PSD. Acronym for process shutdown system.

PVPI. Acronym for present value profitability index.

pycnocline. A steep vertical gradient of density in water column.

radar. Electronic sensor used to locate targets on the ocean.

RCC. Acronym for Rescue Coordination Centre.

RCMP. Acronym for Royal Canadian Mounted Police.

RCS. Acronoym for Radar cross-section. The amount a target reflects a radar signal.

reconnaissance aircraft. A specially equipped remote sensing aircraft.

reconnaissance. Searching a large geographical area.

recruitment. The addition of individual fish to a population through reproduction and immigration.

reflection. The return of a wave or energy incident upon a surface to its original medium. Also, in seismic prospecting, the indication on a record of such reflected energy.

regression. The retreat or contraction of the sea from land areas and the consequent evidence of such withdrawal (such as enlargement of the area of deltaic deposition). Also, any change (such as fall of sea level or uplift of land) that brings nearshore, typically shallow-water environments to areas formerly occupied by offshore, typically deep-water conditions, or that shifts the boundary between marine and non-marine deposition (or between deposition and erosion) toward the centre of a marine basin.

Regulatory Phase. The period and activities associated with the regulatory review of the Development Application. Commences with the filing of the Development Application and ends upon receipt of approval.

replacement. The process of practically simultaneous capillary solution and deposition by which a new mineral of partly or wholly differing chemical composition may grow in the body of an old mineral or mineral aggregate.

reserves. That part of an identified resource from which a usable mineral or energy commodity can be economically and legally extracted at the time of determination.

reservoir. A subsurface, porous, permeable rock body in which oil or gas has accumulated; most reservoir rocks are limestones, dolomites, sandstones, or a combination of these.

residual effect. The effect of a procedure on a component of the environment, or the environment itself, which persists after the implementation of mitigating measures.

resource. An initial volume of oil and gas that is estimated to be contained in a reservoir.

rift. An elongate structural trough bounded by normal faults formed during crustal extension.

riser. A flowline carrying oil or gas from the seabed to the deck of a production platform or a tanker loading platform.

riser base manifold. A simple structure located on the seafloor to act as a termination point for the production riser, satellite wells and transfer lines.

RMS. Acronym for Root Mean Square.

RNC. Acronym for Royal Newfoundland Constabulary.

ROR. Acronym for rate of return.

ro-ro (roll on-roll off). A marine transportation service in which highway or rail vehicles are driven onto or off the vessel on their own wheels.

ROV. Acronym for remotely operated vehicle

RV. Acronym for research vessel.

s. Abbreviation for second.

salinity. The amount of salt in grams dissolved in 1 kg of seawater. The unit is "parts per thousand" expressed a ‰.

sand. A detrital particle smaller than a granule and larger than a coarse silt grain, having a diameter in the range of 0.0625 to 2 mm.

sandstone. Consolidated sediment composed primarily of sand-sized grains.

SAR. Acronym for a) Search and rescue. b) Synthetic aperture radar.

SAWRS. Acronym for Supplementary Aviation Weather Reporting Station.

SBM. Acronym for a) synthetic-based mud or b) Single Buoy Mooring.

scour. (a) Seafloor trench caused by the ploughing motion of an iceberg grounding on the ocean floor. (b) Seafloor erosion caused by strong currents, resulting in the redeployment of bottom sediments and formation of holes and channels.

SCSSV. Acronym for surface controlled sub-surface safety valve.

SD. Abbreviation for Standard Deviation.

sea ice. Any ice floating in the sea. Frozen sea water of varying thicknesses. Also called pack ice.

sedentary. In reference to organisms, those which remain for long periods in one place or have limited movement.

sediment. Solid material, both mineral and organic, that is being or has been transported from its site of origin by air, water or ice, and has come to rest on the earth's surface either above or below sea level.

sedimentary rock. Rocks formed by the accumulation of sediment in water or from air. The sediment may consist of rock fragments or particles, the remains of animals or plants, the product of chemical action or evaporation, or of mixtures of these materials.

SEIS. Acronym for Socio-Economic Impact Statement.

seismic. Pertaining to, characteristic of or produced by earthquakes or earth vibration.

seismicity. The phenomenon of earth movements; seismic activity.

semidiurnal tide. A tide having two high waters and two low waters during a tidal day.

semi-submersible. A drilling or production vessel that has the main buoyancy chambers (pontoons) below the active wave zone to provide enhanced vessel stability.

sequence. A succession of geological events, processes or rocks, arranged in chronological order to show their relative position and age with respect to the geological history as a whole.

sessile. Organisms that are fixed to substrate.

shale. Sedimentary rock consisting dominantly of clay-sized particles, an appreciable amount of which are clay minerals.

shear. A stress causing or tending to cause two adjacent parts of a solid to slide past one another in parallel to the plane of contact.

shelf break. An abrupt change in slope, marking the boundary between the Continental Shelf and the Continental Slope.

shuttle tanker. A ship with large tanks in the hull for carrying oil or water back and forth over a short route.

Side-Looking Airborne Radar (SLAR). Imaging radar used to map pack ice.

sidescan sonar. A sonar device used in seismic surveys to scan the seabed from the side of the survey ship. Can also be used to measure the draft of an iceberg.

Sigma-t. The significant part of the density value of a parcel of water at atmospheric pressure. For instance, the average density of seawater is 1.025 gm/cm^3 or a sigma-t of 25.

silt. A detrial particle smaller than a very fine sand grain and larger than coarse clay, ranging from 0.004 to 0.625 mm in diameter.

siltstone. Consolidated sediment consisting predominantly of silt-sized grains.

sorting. The degree of similarity in grain size of sedimentary particles in a sediment; a measure of the spread or range of the particle-size distribution on either side of an average.

source rock. Sedimentary rock in which organic material under pressure, heat and time was transformed into liquid or gaseous hydrocarbons (usually shale or limestone).

Spider Buoy. Disconnectable interface between the risers and the FPSO.

SPM. Acronym for a) suspended particulate matter, or b) Single Point Mooring.

SRD. Acronym for Search and Rescue Design.

ss [or SS]. Abbreviation for subsea.

stock. A species, group or population that maintains and sustains itself over time in a definable area. A stock is characterized by constancy of the genetic information in the gene pool, and constancy of expression of particular characters controlled either genetically or environmentally. Examples include maintenance of colour variations or particular growth rates.

storm surge. A rise above normal water level due to the action of wind on the water surface and the rise in the level because of atmospheric pressure reduction.

stratification. Division of the water column into layers, or strata, because of differences in water density, structure or temperature.

stratigraphy. A branch of geology concerned with the form, arrangement, geographic distribution, chronological succession, composition, correlation and mutual relationships of rock strata, especially sedimentary.

subaerial. Formed, existing or taking place on the land surface.

sublittoral. The area of the seafloor below the level of extreme low spring water.

submarine canyon. Steep valley-like submarine depression crossing the continental-margin region. Common on the Continental Slope and Shelf, but some continue across the Continental Rise.

surficial. Characteristic of, pertaining to, formed on, situated at or occurring on the Earth's surface; especially, consisting of unconsolidated residual, alluvial or glacial deposits; laying on the bedrock.

surveillance. Searching a geographical area.

SWH. Acronym for significant wave height.

synoptic. Atmospheric conditions existing at a given time over an extended region (for example, a synoptic weather map, which is drawn from observations taken simultaneously at a network of stations over a large area, thus giving a general view of weather conditions).

t. Abbreviation for tonne (a metric ton).

TAC. Acronym for total allowable catch.

td. Abbreviation for total depth.

tectonic. Of, pertaining to or designating the rock structure and external forms resulting from the deformation of the Earth's crust. As applied to earthquakes, it describes shocks not due to volcanic action, collapse of caverns or landslides.

template. Device through which a group of wells is drilled and produced.

TERMPOL. Acronym for Technical Review Process of Marine Technical Systems and Transshipment Sites.

Tertiary. A period of geologic time from approximately 65 million to 2.5 million years ago. The earliest large mammals, grasses and hominids appeared during this period. It is also the period during which most of today's high mountain ranges were formed.

TFSOP. Acronym for Task Force on Oil Spill Preparedness.

thermocline. A steep vertical gradient of temperature in the water column.

threatened species. In Canada, an indigenous species that is likely to become endangered if the factors affecting its vulnerability are not reversed.

till. Non-sorted, non-stratified material (containing particles ranging in size from clay particles to boulers) that has been carried or deposited by a glacier.

TLP. Acronym for tension leg platform.

topside (or topsides) facilities. The oil- and gas-producing and support equipment located on the top of an offshore structure.

towability. Physical features of an iceberg that permit a tow rope to maintain a grip on the berg while being towed.

TPH. Acronym for total petroleum hydrocarbons.

transgressive (or transgression). Refers to the encroachment of the sea upon the land.

transport (or transportation). A phase of sedimentation that includes the movement by natural agents (such as flowing water, ice, wind or gravity) of sediment or of any loose material, either as solid particles or in solution, from one place to another on or near the earth's surface (for example, the drifting of sand along a seashore under the influence of currents, the creeping movement of rocks on a glacier or the conveyance of silt, clay and dissolved salts by a stream).

trap. The mechanism or feature causing hydrocarbon to be retained in a reservoir rock.

tree. (a) An arrangement of valves placed on top of a well to control flow from the well. (b) An arrangement of valves and fittings attached to the tubing head to control flow and provide access to the tubing string.

TSR. Acronym for temporary safe refuge.

trophic level. The position an organism occupies in the food web, determined by the number of energy transfer steps needed to get to that point.

tropical storm. A tropical cyclone with wind speeds from 61 to 114 kmh.

TSS. Acronym for total suspended solids.

tunicates. Globular or elongated saclike filter-feeding animals attached to the substrate at one end, and with two openings, in-current and ex-current, at the free end.

turbidity. The state or condition of having the transparency or translucency of water disturbed, as when sediment in water is stirred up.

turret. A low, tower-like structure capable of revolving horizontally within the hull of a ship and connected to a number of mooring lines and risers. It allows the ship to rotate with the weather while maintaining a fixed mooring system.

UA. Acronym for (NAFO) Unit Area.

umbilical. Device through which control of subsea instrumentation is maintained from the FPSO.

upwelling. Light surface water transported away from the coast (by action of winds parallel to it) and replaced near the coast by heavier subsurface water.

USGOM-OCS. US Gulf of Mexico Outer Continental Shelf.

UTC. Acronym for Universal Time Clock.

VEC. Acronym for valued environmental component.

VHF. Acronym for very high frequency.

viscosity. The measure of the resistance of a fluid to flow; the lower the viscosity number, the more readily the fluid will flow.

water-based mud. A drilling mud in which the continuous phase is water. See drilling mud.

water column. The vertical dimension of a body of water (that is, the water between a reference point or area on the surface and one located directly below it on the bottom).

wave hindcasting. Prediction of waves based on past meteorological conditions.

wave rider buoys. An instrumental buoy moored in a specific marine location, used to collect oceanographic material.

well workover. A program of work performed on an existing well; may involve re-evaluating the production formation, clearing sand from producing zones, jet lifting, replacing downhole equipment, deepening the well, acidizing or fracturing, or improving the drive mechanism.

White Rose Development. "Development" refers to all phases of the project, from the decision to go ahead with construction through to abandonment of the field.

WHMIS. Acronym for Workplace Hazardous Materials Information Systems.

wireline. A rope composed of steel wires twisted into strands that are in turn twisted around a central core of hemp or other fibre to create a rope of great strength and flexibility; used to lower and raise logging instruments and bottom line-pressure gauges.

WMO. Acronym for World Meteorological Organization.

WOAD. Acronym for World Offshore Accident Databank.

WOR. Acronym for water-oil ratio.

workover. Intervention procedure performed on a well involving rig, wireline and/or coil tubing to improve well integrity or well performance.

WSF. Acronym for water soluble fraction.

yr. Abbreviation for year.

ZOI. Acronym for zone of influence.

zooplankton. The animal component of those organisms drifting or weakly swimming in the ocean largely at the mercy of prevailing currents.