BRITISH COLUMBIA
OFFSHORE OIL AND GAS
TECHNOLOGY UPDATE

October 19, 2001

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TECHNOLOGY UPDATE

Prepared For:

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PREFACE

In 1998, the British Columbia Information, Science and Technology Agency, on behalf of the Premier's Advisory Council on Science and Technology, tendered and issued a contract to AGRA Earth and Environmental Limited (AGRA) (St. John's, Newfoundland office) to review and report on offshore development technologies. The AGRA study examined the status of the offshore exploration industry in both Canada and elsewhere, particularly as it related to the issues identified in the Envrionmental Assessment Panel Report on offshore oil and gas issues dated 1986. The 1998 report was not released by the Province. Specific objectives of the 1998 report were to provide the Premier's Advisory Council on Science and Technology with:

- the status of the offshore exploration industry in Canada and elsewhere;
- information regarding the status of offshore issues as they relate to issues identified in the 1986 Panel Report; and
- a review of advancements in the field and experience in other jurisdictions which would be applicable to British Columbia and a summary of information gaps that might prevent a full assessment of oil and gas exploration and development risks and impacts.

The Province of British Columbia has recently committed to review the existing moratorium on offshore oil and gas development. As the lead coordinating agency for oil and gas resources off the coast of British Columbia, the Ministry of Energy and Mines issued a Request for Proposals on August 20, 2001 to prepare an update of the 1998 AGRA report using existing information and literature. The intent of this update report is to document background information for use by the government in reviewing the moratorium. The scope of work for this contract was specifically to:

- review the 1986 panel report (Offshore Hydrocarbon Exploration, a Report and Recommendations of the West Coast Offshore Exploration Environmental Assessment Panel) and the 1998 AGRA report (Review of Offshore Development Technologies); and
- update the 1998 review to consider additional scientific and technological advancements, changes in regional economics and developments in other jurisdictions.

The focus of this update was on offshore oil and gas engineering, environment and socio-economic factors, and state-of-the-art technologies. As this is an update of the 1998 AGRA report and not a new study, the project team used portions of the previous text. Those segments of the 1998 report that are incorporated verbatim, or with minor edits, have been italicized for clear identification. Rather than address specific changes that have occurred between 1986 and 2001 or between 1998 and 2001, this update has focussed on updating the information in the AGRA report and addressing data and information gaps with an emphasis on current issues and future trends in the offshore industry in Canada and around the world. This report is not intended to be a comprehensive assessment of all available engineering technologies and approaches to the design of offshore structures or an environmental impact assessment of offshore oil and gas activities. Rather, it is intended to be a background report summarizing the latest technologies, their application to the safety of offshore oil and gas operations and potential environmental effects of offshore oil and gas activities. This report is intended to be a "stand alone" document and the reader should not have to refer to the previous reports to understand the issues.

TABLE OF CONTENTS

Page No.

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

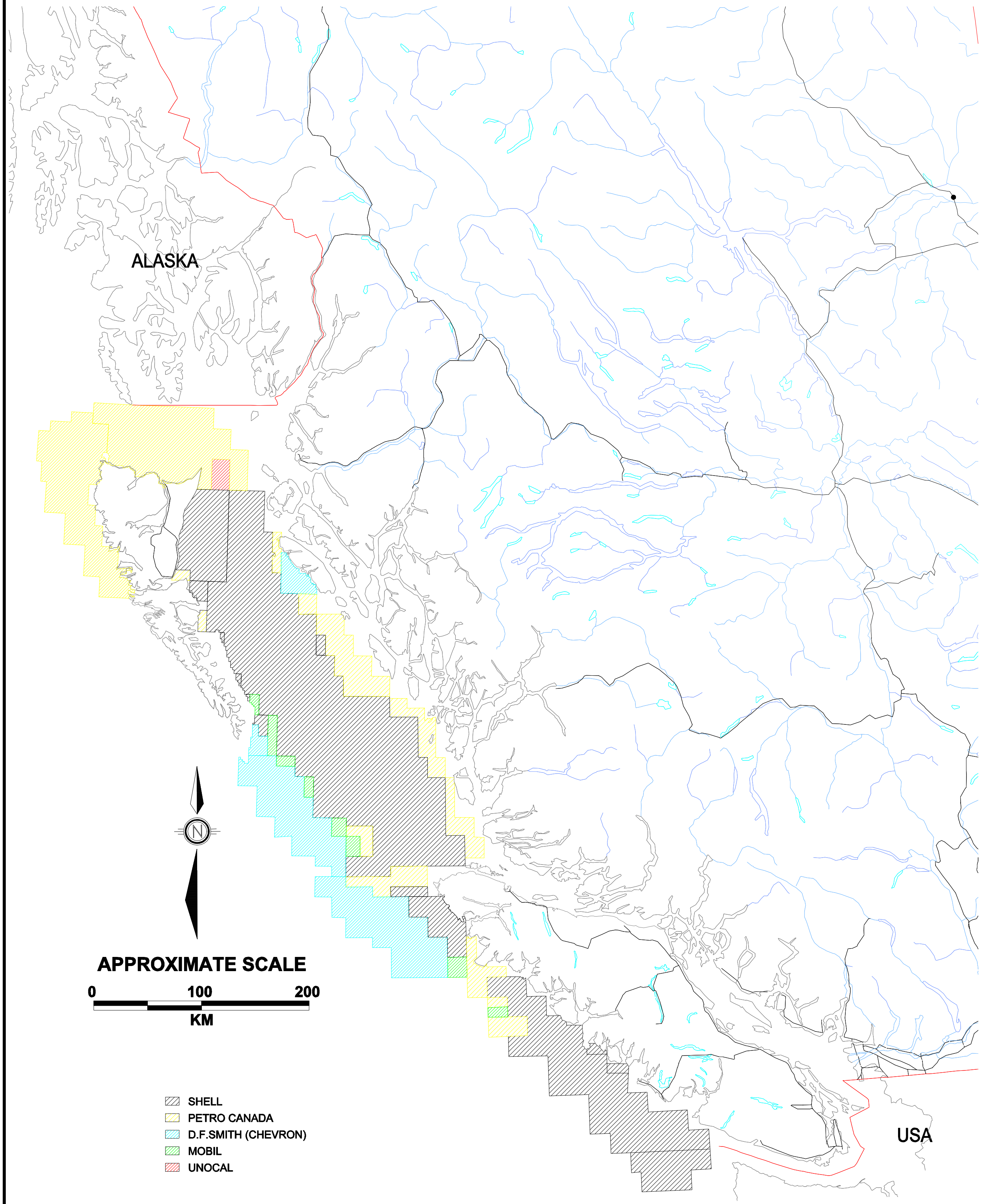
1.0 INTRODUCTION

In 1958, the first offshore seismic activity took place in the Queen Charlotte Basin off Canada's west coast. A moratorium was imposed on exploration drilling in the coastal waters between Vancouver Island and Alaska by the Province of British Columbia in 1959. *By 1961 Shell Canada Limited had begun acquiring exploration permits for offshore areas in Hecate Strait, Queen Charlotte Sound and on the continental shelf off the western coast of Vancouver Island. This led the company to conduct geological mapping and offshore seismic surveys between 1963 and 1967.* The Province's moratorium was lifted in 1966 and between 1967 and 1969 *Shell drilled 14 wells, eight of which were in the Hecate Strait - Queen Charlotte Sound.* The locations of these wells is shown on Figure 1.1. *By 1970 Shell had entered into a farm-out agreement with Chevron Canada Resources whereby Chevron would earn an interest in the Shell offshore area by conducting seismic surveys and drilling two deep exploratory wells.* Offshore British Columbia oil and gas lease tenures as of 2001 are shown on Figure 1.2. *However, exploration soon came to a standstill. In 1972 the federal government imposed a moratorium preventing crude oil tankers en route from the Trans-Alaska pipeline terminal at Valdez, Alaska from travelling through the Dixon Entrance, Hecate Strait and Queen Charlotte Sound. Shortly afterwards, the federal government placed a moratorium on drilling in these waters. In 1981, the Province of British Columbia declared the region an Inland Marine Zone. Simultaneously, a moratorium was placed on offshore exploration in Johnstone Strait south of Telegraph Cove and in the Straits of Georgia and Juan de Fuca. These moratoria remain in effect today.*

Consideration was given to lifting the moratorium in 1984 to allow the petroleum companies holding leases in the region to undertake exploration programs. A five person panel was appointed and held public information meetings and public hearings throughout northern coastal British Columbia during the fall of 1984 and 1985 respectively. Chevron Canada Resources Ltd. acted as a proponent and Petro-Canada initially participated but withdrew in November 1984. Based on information obtained at those meetings, the Panel delivered its report in April 1986. Entitled "Offshore Hydrocarbon Exploration, a Report and Recommendations of the West Coast Offshore Exploration Environmental Assessment Panel", the report contained 92 (ninety-two) recommendations covering a broad spectrum of issues including:

- *the environmental assessment process;*
- *seismic surveying;*
- *routine exploratory drilling and support operations;*
- *socio-economic effects of routine operations;*
- *hydrocarbon blowouts;*
- *fate and effects of oil in the marine environment;*
- *oil blowout contingency;*

Figure 1.1 Exploration Well Locations



NORTH COAST OFFSHORE BRITISH COLUMBIA OIL & GAS TENURES

OFFSHORE OIL AND GAS TECHNOLOGY UPDATE

BC MINISTRY OF ENERGY AND MINES

DATE:	SCALE:
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Jacques Whitford

- *planning and countermeasures, and*
- *compensation and managing for environmental protection.*

On the basis of the report and its recommendations, both the provincial and federal governments decided to negotiate a Pacific Accord, which would have allowed the lifting of the moratorium. However, spills from a tanker and *a tug in 1989* (Exxon Valdez and Nestucca barge) *and the subsequent public reaction to these events persuaded the two governments to continue an indefinite extension to the moratorium with no mechanism for its review.*

1.1 Canadian Offshore Oil and Gas Production in a Global Context

Canada is the third largest producer of natural gas and the 13th largest producer of crude oil in the world. In 2000, Canada produced 2.2 million barrels per day of crude oil and 6.3 trillion cubic feet of natural gas per year (CAPP 2001).

While Canada has long been producing oil and gas from on-land developments, it is a very recent participant in offshore oil and gas production. On the East Coast, one development has been decommissioned (Cohasett-Panuke, NS). There are two producing fields on the East Coast (Hibernia oil field, NF and Sable gas field, NS), one nearing development (Terra Nova, NF), one nearing the end of the regulatory approvals process (White Rose, NF) and several in the exploration stages and early stages of the regulatory approvals process. On the West Coast, the Province of British Columbia imposed a moratorium on exploration drilling in the coastal waters between Vancouver Island and Alaska in 1959. The moratorium was temporarily lifted between 1966 and 1972, during which a total of 14 exploratory wells were drilled, and it remains in effect today.

To put Canadian offshore oil and gas development in context, the following provides a brief overview of the state of offshore oil and gas development in other select jurisdictions worldwide:

- Pacific Outer Continental Shelf Region – there are currently 24 oil and gas production facilities (operated by six companies) in federal waters off the coast of California, and with one exception, all are still in operation. As of April 2001, these facilities have produced over 1 billion barrels of oil and 1.2 trillion cubic feet of gas (MMS Pacific OCS Region web site).
- Gulf of Mexico Region – while a recent study (Pulsipher *et al.* 2001) indicated that the total number of federal water (Outer Continental Shelf) oil and gas platforms in the U.S. Gulf of Mexico would begin a slow but steady decline to 2023, in 2001 (MMS Gulf of Mexico Region web site), in the Gulf of Mexico Region there were:
    - 7,480 active leases (as of September 17, 2001),
    - 40,513 approved applications to drill (as of September 17, 2001),
    - 4,025 active platforms (as of September 17, 2001),
    - 54 wells being drilled (as of February 2001), and
    - 6,440 wells producing (as of February 2001).

- Alaska Outer Continental Shelf Region – since offshore drilling began in the Alaska Outer Continental Shelf Region in 1975, nearly 100 wells have been drilled. Of the three current development exploration activities, one exploration plan was withdrawn by the developer and one received federal approval (and is expected to begin production in late 2001). The required development and production plan for the third proposal has been recently submitted, for which the draft Environmental Impact Statement (EIS) was released from the assessment process and is expected to be finalized by the end of 2001 (MMS Alaska OCS Region web site).
- United Kingdom North Sea – natural gas first came ashore from the United Kingdom North Sea in 1967; the first oil came ashore in 1975, with 1976 the first full year of production from a United Kingdom North Sea oil field. As of the beginning of 1999, 204 offshore fields in the United Kingdom North Sea were in production, of which 109 were producing oil, 79 producing gas and 16 producing condensate. In 1998, the United Kingdom North Sea produced 132.6 million tonnes of oil and 95.6 billion cubic feet of gas (UKOOA web site).
- Norwegian Continental Shelf – as of December 2001, there were 62 offshore oil and gas fields on the Norwegian continental shelf, 45 of which are producing fields (40 in the Norwegian North Sea and five in the Norwegian Sea) and 10 have shut down. Seven of the oil and gas fields (all in the Norwegian North Sea) have been approved for development and operation but have not yet started production (Norwegian Petroleum Directorate web site).
- Australia – the Australian oil and gas industry has been operating in the marine environment for 25 years and drills over 100 wells each year (both offshore and onshore). As of 2000, 19 development wells (five in first quarter 2001), and 50 explorations wells (18 in first quarter 2001) were spudded in offshore Australia (APPEA web site).

2.0 REGULATORY REGIME

There is currently no regulatory process in place in British Columbia with the specific mandate to review and approve offshore oil or gas exploration or production activities. The Oil and Gas Commission, and the British Columbia Environmental Assessment Office are the existing provincial regulatory bodies that address oil and gas activities and environmental approval processes in the province. The Oil and Gas Commission and the BC environmental assessment process are described below. The review and approval processes for the oil and gas industry in the Atlantic provinces are also described. Numerous other pieces of provincial and federal legislation that are not within the scope of this update, such as the provincial *Waste Management Act* and the federal *Transportion of Dangerous Goods Act*, would also apply to various activities undertaken in the development and operation of an offshore oil and gas industry.

2.1 Oil and Gas Commission

The Oil and Gas Commission (OGC) is the Province of British Columbia's crown corporation responsible for regulating most aspects of the upstream oil and gas industry in the province, including crude oil, natural gas and pipeline activities. The OGC is a relatively new body, established by enactment of the *Oil and Gas Commission Act* in June 1998. It assumes most of the oil and gas regulatory responsibilities formerly held by the Ministries of Energy and Mines, Forests, and Environment, Lands and Parks. An integral part of the OGC's regulatory responsibility evolves from the *Petroleum and Natural Gas Act* and the *Pipelines Act,* and affiliated regulations. As all oil and gas exploration and production in BC to date has been land-based, none of the OGC processes have been tailored toward work in a marine environment.

The OGC is based in Fort St. John and also has offices in Victoria and Fort Nelson. The Commission is made up of 7 branches: Commissioner's Office; Applications and Approvals; Aboriginal Relations and Land Use; Corporate Services; Compliance and Enforcement; Engineering and Geology; and Legislation, Policy and Special Projects. The OGC's mandate is to provide efficient processes for the review of applications related to the oil and gas sector (*i.e.* well and road development, geophysical exploration activity, pipeline and facilities), ensuring that decisions are made in the public interest and having regard for environmental, economic and social impacts. More specifically, the OGC's mandate is to assist development of the oil and gas industry by streamlining the applications and approval processes while maintaining provincial environmental standards. Section 3 of the *Oil and Gas Commission Act* states that the purposes of the OGC are to:

a) regulate oil and gas activities and pipelines in British Columbia in a manner that
    i) provides for the sound development of the oil and gas sector, by fostering a healthy environment, a sound economy and social well being,
    ii) conserves oil and gas resources in British Columbia,
    iii) ensures safe and efficient practices, and
    iv) assists owners of oil and gas resources to participate equitably in the production of shared pools of oil and gas;
b) provide for effective and efficient processes for the review of applications related to oil and gas activities or pipelines, and to ensure that applications that are approved are in the public interest having regard to environmental, economic and social effects;
(c) encourage the participation of First Nations and aboriginal peoples in processes affecting them;
(d) participate in planning processes; and
(e) undertake programs of education and communication in order to advance safe and efficient practices and the other purposes of the Commission.

To support the development permit application process, the OGC has developed a number of checklists to ensure proponent's applications are complete and entered into a Memorandum of Understanding (MOU) with the Treaty 8 First Nations having Traditional Territories in the Peace River basin (West Moberly, Saulteau, Prophet River, Fort Nelson, Halfway, Blueberry, Doig, and Dené Tha'). This MOU clearly outlines the approval process with respect to First Nations review of the application, process for identification of potential Treaty Rights infringement(s) and timing. In addition, approximately 60 approval application checklists have been prepared for most activities requiring approval such as: public consultation; geophysical - crown and private land; wells - crown, private, and agricultural lease; roads; pipelines - crown and private land; powerlines; quarries; airstrips; on-lease and off-lease facilities; and others.

Applications for well, geophysical and pipeline projects must assess project effects on the environment (forest, land and habitat), First Nations and archaeology issues in the application. Further, all applications to the OGC are required to assess the need for public consultation and ensure that a consultation process commensurate with the project scope is undertaken. This consultation process must include all stakeholders potentially impacted by an application, including First Nations. The application forms for specific development (geophysical, well and pipeline) contains a section for public consultation and requires the applicant to provide a record of all consultation conducted. This includes documentation of parties consulted, means of contact, dates, notes, issues raised, how those issues were addressed and if there are any outstanding or unresolved concerns. As part of the Pre-Application review process, the OGC assesses the consultation process and the Aboriginal Affairs, Policy and Land Use Branch specifically reviews the Application and consultation with respect to potential Treaty Rights infringement for Treaty 8 First Nations.

To speed the screening process, the OGC has developed an application sorting function based on the complexity of the project. The process involves the division of applications into Simple, Normal, or Complex categories. This screening process limits application routing to only the required reviews. The streamlined review process also gives proponents a more accurate estimate of the processing time required for each application. Factors considered by the OGC for classification of an application for geophysical activities, wells and pipelines are outlined in Table 2.1. If the application is complete and all issues have been addressed to the satisfaction of the OGC, approval is granted through a single approval document.

2.2 British Columbia Environmental Assessment Process

The environmental approval process for large projects in British Columbia is regulated through the British Columbia Environmental Assessment Office (BCEAO). All projects that are considered a reviewable project pursuant to the *Reviewable Projects Regulation* of the British Columbia *Environmental Assessment Act* (*BCEAA*) must obtain an approval through the environmental assessment review process. The *BCEAA* process features a multi-staged project review. Depending on the resolution of environmental issues, the review may require up to three stages: Stage 1 – Application; Stage 2 – Project Report; Stage 3 – Public Hearing. A project may be approved after any of these stages. The test of whether a project moves to the next Stage is whether or not all environmental issues have been sufficiently resolved. To date, no review has progressed to Stage 3.

Table 2.1 OGC Applications Identification Table

	GEOPHYSICAL	WELLS	PIPELINES
SIMPLE*	**PRIVATE:** **Geophysical Program** on private land or agricultural lease that includes the following: No stream crossings to be crossed with mechanical equipment. No crown timber. All road use permits in place. *Archaeological overview assessment (pre-application) is completed with no recommendation for an Archeological Impact Assessment or application is in an accepted area of very low potential.* **CROWN:** **Geophysical Program** on crown land *Note: An application that does not require Aboriginal consultation, an "Application Pre-Assessment" form must be completed and signed off by the Director of Aboriginal Affairs and Land Use*. No cutting permit required. Existing access. Not in special management areas. No stream crossings to be crossed with mechanical equipment. All road use permits in place. No range tenures impacted or agreements already in place. Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated.	**PRIVATE:** **Well** (and access) on private land or agricultural lease that includes the following: Sweet gas objective (i.e. Bluesky, Gething, Jean Marie formations) Land owner (leaseholder) agreement(s) submitted. *Archaeological overview assessment (pre-application) completed or application is in an accepted area of very low potential.* Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines No stream crossings. No crown timber. Road use permits in place. Schedule A pre-site assessment submitted. **CROWN:** **Well** on crown land: *Note: An application that does not require Aboriginal consultation, an "Application Pre-Assessment" form must be completed and signed off by the Director of Aboriginal Affairs and Land Use*. No cutting permit required. Sweet gas objective (i.e. Bluesky, Gething, Jean Marie formations) Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated. Not in special management areas No stream crossings. No range tenures impacted or agreements already in place. Schedule A pre-site assessment submitted. No Certificate of Restoration on existing site	**PRIVATE:** **Pipeline** on private land. Land owner agreement(s) in place. *Archaeological overview assessment (pre-application) completed or application is in an accepted area of very low potential.* No crown timber. Road use permits in place. No stream crossings **CROWN:** **Pipeline** on crown land: *Where low infringement has been identified, as reviewed and approved by Aboriginal Affairs and Land Use Policy Branch.* Within existing well site Rights of Ways or Licenses of Occupation. Wholly within an existing pipeline Right of Way with no stream crossings or no crown timber removal. Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated.

	GEOPHYSICAL	WELLS	PIPELINES
AMENDMENTS	**Minor Amendments:** Helipads for functionality as per Ministry of Forests and WCB guidelines. *Note: An application that does not require Aboriginal consultation, an "Application Pre-Assessment" form must be completed and signed off by the Director of Aboriginal Affairs and Land Use.* Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated. No major issues identified in review of original application. Private land with no major issues identified on original application.	Minor Amendments-Wells: addition of borrow pits, decking sites, remote sumps, workspaces, minor access changes. *Note: An application that does not require Aboriginal consultation, an "Application Pre-Assessment" form must be completed and signed off by the Director of Aboriginal Affairs and Land Use.* Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated. No major issues identified in review of original application.	**Minor Amendments-Pipelines: addition or relocation of borrow pits or temporary workspaces.** *Note: An application that does not require Aboriginal consultation, an "Application Pre-Assessment" form must be completed and signed off by the Director of Aboriginal Affairs and Land Use.* Minimal public/stakeholder impact or detailed public consultation completed as outlined in the Oil and Gas Activity Public Consultation Policy and Guidelines and issues effectively mitigated. No major issues identified in review of original application.
NORMAL*	All applications that are not described in the simple or complex categories.	All applications that are not described in the simple or complex categories.	All applications that are not described in the simple or complex categories.
COMPLEX*	Any applications that are: Proposed in environmentally sensitive area as identified in the Land and Resource Management Plan as a Special Management Zones, adjacent to, or crossing major fish bearing streams. *Projects that are identified as having a medium or high probability of infringement on First Nation Treaty Rights. (as outlined in the MOU'S signed by the member First Nations of Treaty 8 and the Province of BC)* *Archaeological pre-impact assessment required, and not completed prior to the application submission*. Applications located outside North Eastern BC (Fort Nelson, Fort St. John, Dawson Creek) MOF Districts 3D Applications	Any applications that are: Proposed in environmentally sensitive area as identified in the Land and Resource Management Plan as a Special Management Zones, adjacent to, or crossing major fish bearing streams. Special sour wells. *Projects that are identified as having a medium or high probability of infringement on First Nation Treaty Rights. (as outlined in the MOU'S signed by the member First Nations of Treaty 8 and the Province of BC)* *Archaeological pre-impact assessment required, and not completed prior to the application submission.* Applications located outside North Eastern BC (Fort Nelson, Fort St. John, Dawson Creek) MOF Districts Well and access proposed for summer construction in traditional winter access areas	Any applications that are: Proposed in environmentally sensitive area as identified in the Land and Resource Management Plan as a Special Management Zones, adjacent to, or crossing major fish bearing streams. *Projects that are identified as having a medium or high probability of infringement on First Nation Treaty Rights. (as outlined in the MOU'S signed by the member First Nations of Treaty 8 and the Province of BC)* *Archaeological pre-impact assessment required, and not completed prior to the application submission*. Applications located outside North Eastern BC (Fort Nelson, Fort St. John, Dawson Creek) MOF Districts

* Criteria may be changed at the discretion of the Director

Another feature of *BCEAA* is specific timelines for project reviews. The schedule assumes that the BCEAO, the Project Committee, the Ministers and regulators take the maximum allowable time for each step in the review process permitted under BC*EAA*. There remains some potential, therefore, to reduce the overall duration of the regulatory approval process if the parties involved do not use their maximum allowable time to review the Application.

A Stage 1 Application to the BCEAO must contain all of the following information upon submission before it will be accepted for review:

- a description of the purpose and major components of the project;
- existing information pertaining to environmental, social, economic, cultural, heritage and health characteristics and conditions in the vicinity of the project;
- on and off site facilities associated with the project;
- the construction plan for the project and a timetable for the completion of construction;
- any new or expanded public works or undertakings that will be required because of the project;
- potential effects of the project;
- the measures that the proponent proposes in order to prevent or mitigate adverse effects;
- any relevant plans pertaining to land use and to related resource issues in the area of the project that are authorized under an enactment;
- public information distribution activities and consultation activities undertaken by the proponent and a summary of the public response and of the issues identified;
- any program of public information distribution or consultation proposed by the proponent during the next stages of project planning and review;
- information distribution activities and consultation undertaken by the proponent with a First Nation and a summary of the First Nation’s response and of the issues identified;
- any program of information distribution or consultation proposed by the proponent with a First Nation during the next stages of project planning and review;
- any discussions undertaken by the proponent about the effects of the project, with ministries or agencies of the government of British Columbia, with departments or agencies of the government of Canada, with municipalities or regional districts or with British Columbia’s neighbouring jurisdictions; and
- the issues identified in the discussion referred to in the previous point.

Within seven (7) days of the submission of the Application, the Executive Director screens and accepts the Application for review. Once the Application is accepted by the BCEAO, the Executive Director establishes a Project Committee to review the proposed project and provide recommendations. The Project Committee can include representatives from the following agencies:

- the government of British Columbia;
- the government of Canada;
- any municipality or regional district in the vicinity of the project or in which the project is located;

- any First Nation whose traditional territory includes the site of the project or is in the vicinity of the project; and
- any of British Columbia's neighbouring jurisdictions in the vicinity of the project.

After the Application is accepted for review, the Project Committee will specify the length of the review period of the Application (30-75 days). At the same time, the Executive Director must advertise a public notice of the proposed project, soliciting comments from the public and other agencies in the British Columbia government and the federal government within the review time frame of the Project Committee. In addition, a copy of the Application is placed on the Project Registry for referral purposes.

The Project Committee provides comments and recommendations regarding the Application and the comments received from the public within 40 days of the completion of the Application review period. Upon the receipt and review of the Project Committee's recommendations, the Executive Director will either request a Stage 2 review of the proposed project (a Project Report), or will forward the Application and Project Committee comments to the ministers for a decision, to be made within 30 days. Once the Application is approved by the ministers, a project approval certificate is issued and the project may proceed.

2.2.1 Concurrent Regulatory Approvals

At any time after the acceptance of the Application for review by the Executive Director and the Project Committee, the proponent may request that concurrent consideration be given to the approval of permits and licenses directly related to the proposed project. The proponent must submit a formal notice to the Executive Director requesting that applications for licenses and permits be reviewed concurrently with the Application.

Concurrent regulatory approvals could lead to expeditious approvals on proposed projects. Where a proponent requests concurrent review of other approvals, the Project Committee coordinates this review with the review of the Application. The appropriate regulatory agencies will proceed with processing the applications for specified licenses and permits related to the proposed project, following their normal procedures. However, this processing must be completed within the specified review period for the Application. The specific permits requested, if approved, will be issued with 30 days of BC*EAA* certification.

Applications for permits and licenses may need to incorporate detailed, and possibly final, engineering design information. The ability to process concurrent approvals will depend upon the proponent providing the necessary information in adequate detail.

2.2.2 Public Consultation

Prior to the submission of the Application to the BCEAO, the proponent is expected to begin consultation with the public. Consultation at the pre-Application stage should focus on initial scoping of public interests and concerns, as the proponent becomes familiar with key stakeholders who will need to be consulted on an ongoing basis. Information sessions for the public should be advertised and held during the pre-Application stage. A comprehensive public consultation program will ensure environmental issues are identified early and can be dealt with effectively in the Application.

The Application should include documentation and a summary of all public consultation activities prior to the submission of the Application. An up-to-date mailing list of all agency/public contacts and the addresses of neighbouring landowners and businesses should be included in the Application. In addition, the proponent must include a description of plans for future consultation activities and their timing during the Application review stage.

Once the Application has been submitted and accepted by the Executive Director of the BCEAO, the public must be formally notified of the availability of the Application for review. The Executive Director is required to advertise a notice of the availability of the Application and to invite public comments during the specified Application review time period. The proponent is also required to advertise a notice about the availability of the Application for comment, and to carry out any public consultation plans outlined in the Application document during the specified review period.

Following the review of the Application and the submission of comments from the public, the proponent will be provided with the comments submitted to the BCEAO and will have a brief opportunity to provide a written reply. The proponent is required to respond to the public comments in a timely manner so that the Project Committee can take these responses into consideration within the time allotted to make recommendations to the Executive Director.

In general, the costs of Application distribution, advertisement, or public consultation will be the responsibility of the proponent.

2.2.3 Federal Environmental Impact Assessment

An environmental assessment pursuant to the *Canadian Environmental Assessment Act* (*CEAA*) may be triggered if the proposed project involves the federal government in any of the following ways:

- the proponent is an agent of the federal government;
- the federal government provides funding for the proposed project;
- the proposed project requires leasing or buying land from the federal government; or
- the proposed project requires a permit or a license from a federal authority.

In the case that a federal environmental assessment is triggered, the Province of British Columbia and the federal government have negotiated a bilateral agreement to harmonize requirements for environmental assessments under both processes. The purpose of this bilateral agreement is to provide a streamlined approach to federal-provincial environmental assessments and to reduce costly delays in project approval and repetition of environmental assessment information submitted to regulatory agencies. In order to achieve this "one project - one assessment" objective, federal agencies will designate the process of screening or comprehensive study under the *Canadian Environmental Assessment Act* to the provincial Environmental Assessment Office. At the conclusion of the environmental assessment, both governments will make their respective decisions. In this manner, each government retains its decision-making role, but the two decisions are made on the basis of information gathered and analyzed through a single process.

2.3 Atlantic Canada

The approvals process for offshore oil and gas exploration in Atlantic Canada is regulated through the Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB), the Canada-Newfoundland Offshore Petroleum Board (C-NOPB), the National Energy Board (NEB), and/or provisions of the *Canadian Environmental Assessment Act*. Development in most of offshore Nova Scotia is subject to the provisions of the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act* and the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act* (the Accord Acts). Development in offshore Newfoundland 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 Acts and their regulations and guidelines are found on the C-NSOPB and C-NOPB websites. The information in this section is from the Acts and their regulations and the Nova Scotia and Newfoundland reports in The Regulatory Roadmaps Projects compiled by the Atlantic Canada Petroleum Institute (ACPI) (ACPI and Erlandson & Associates 2001a; 2001b) and from the recently completed White Rose Oilfield Comprehensive Study (Husky Oil 2000).

2.3.1 Roles of the Boards

The C-NSOPB and C-NOPB are independent joint agencies representing the Government of Canada and the Governments of Nova Scotia and Newfoundland and Labrador, respectively, and are responsible for management of the hydrocarbon resources (including regulation and safe practices) in the Nova Scotia and Newfoundland offshore areas pursuant to the Accords Acts. The C-NSOPB was established in 1987; the C-NOPB in 1985. In carrying out their mandates, the Boards operate autonomously in making their decisions, other than those described in the Accords Acts as "fundamental decisions", which are subject to the approval of the federal and provincial energy ministers. The Boards continuously monitor the activities of offshore operators in the areas of safety, environmental protection, resource management, and industrial benefits (as per the provisions of the Accord Acts as they relate to providing full and fair opportunity to workers and companies in Canada, and particularly in Nova Scotia and Newfoundland and Labrador, to participate in the supply of goods and services used in the offshore activity).
The C-NSOPB's principal responsibilities include (C-NSOPB website):

- ensuring the safe conduct of offshore operations;

- protection of the environment during offshore petroleum activities;
- management of offshore oil and gas resources;
- review of industrial benefits and employment opportunities;
- issuance of licenses for offshore exploration and development; and
- resource evaluation, data collection and distribution.

The C-NOPB's responsibilities include (C-NOPB website):

- the sale of interest in lands;
- the issuing of exploration licenses;
- approvals and authorizations pertaining to exploration activities;
- the declaration of Significant and Commercial discoveries;
- the issuing of production licenses;
- decisions relating to the commencement, continuation, and suspension of drilling and production;
- the administration of regulations; and
- the exercise of emergency powers pertaining to safety, environmental protection, and resource conservation.

In fulfilling these roles, the C-NSOPB/C-NOPB will often place conditions upon a development as they relate to environmental protection (requiring an environmental protection plan for each phase of a project), environmental monitoring (conducting environmental effects monitoring to validate the potential effects predictions made in environmental assessment reports), and worker safety (requirements for safety plans, conducting concept safety analyses). In addition to placing conditions on planning processes, the C-NSOPB/C-NOPB will also often require commitments/place conditions upon the design of the project (e.g., requiring specific safety design considerations be included, such as double-hulled vessels for operating in waters with pack ice and icebergs).

The C-NSOPN/C-NOPB also provide regulatory advice/direction on guidelines, such as the Offshore Chemical Selection Guidelines or the Offshore Waste Treatment Guidelines. These latter guidelines, developed in 1996 by both the C-NSOPB and C-NOPB in conjunction with the National Energy Board (NEB), are currently under review and the two provincial Boards enforcement of these Guidelines can vary. For example, an important issue is the disposal of drill cuttings (refer to Section 6.1.3.1), and whether or not they can be discharged over the side. The current (1996) Offshore Waste Treatment Guidelines sets a 15 percent retention of oil on cuttings (15 g/100 g or less of dry solids) for treated drill cuttings disposed over the side. The C-NSOPB currently holds with the North Sea model of allowing 1 percent oil retained on cuttings for drill cuttings to be disposed over the side (this limit has been in effect since January 1, 2000 (C-NSOPB Policy on Discharge of Oil-Based Muds)). As this limit is not possible to meet under current best available technology, developments must re-inject cuttings back into the field, or ship cuttings to shore for approved disposal. The C-NSOPB has recently allowed exemptions to the 1 percent limit for several exploration drilling projects to the USEPA limit of 6.9

percent wet weight on cuttings if the proponent accomplishes it using a demonstration technology. The C-NOPB, while currently allowing over the side discharge at the 15 percent limit (they issued an Amendment to the Offshore Waste Treatment Guidelines on the "Use of Synthetic Based Drilling Mud in the Offshore Newfoundland Area"), is reviewing reducing the limit to 8 percent, which is theoretically possible with best available technology.

2.3.2 Development Application Process

2.3.2.1 Project Approval

The Accord Acts are very similar, as are the development regulations, approvals and authorizations. Both Accord Acts will be discussed in tandem, with any significant differences indicated.

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 license 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-Nova Scotia Industrial Benefits and Employment Plan or Canada-Newfoundland Benefits Plan (Benefits Plans) is a statutory pre-condition to approval of the Development Plan.

Proponents who wish to develop a field in the Nova Scotia/Newfoundland offshore area make the C-NSOPB/C-NOPB aware of their intentions as early as possible by meeting with the C-NSOPB/C-NOPB to discuss the proposal. Subsequently, a proponent submits written notice and description of the proposed development to the C-NSOPB/C-NOPB. A proponent must then submit a Development Application (DA).

The following documents must be included with every DA:

- Development Plan;
- Canada-Nova Scotia Benefits Plan or Canada-Newfoundland Benefits Plan (depending on jurisdiction); and
- Development Application Summary.

The C-NSOPB/C-NOPB may also require one or more auxiliary documents including:

- Environmental Impact Statement (EIS) (including a Socio-Economic Impact Statement (SEIS)) (Nova Scotia process) or separate EIS/SEIS documents (Newfoundland process).
- Generic Safety Plan (including a Concept Safety Analysis);
- Environmental Protection Plan; and
- any other documentation deemed necessary by the C-NSOPB/C-NOPB (these are referred to as Part

II documents and contain specific geotechnical and engineering data such as reservoir modelling – these can only be released to the public with permission from the proponent due to their proprietary nature).

A Development Plan provides the C-NSOPB/C-NOPB with a description of all phases of the proposed offshore hydrocarbon development process associated with the proposed project. It also provides sufficient information to enable the C-NSOPB/C-NOPB to conduct a public review of the proposed project activities, if it deems such a review to be necessary.

A Development Plan outlines the work that is to be done during all subsequent phases of the project, and the procedures that will be used in completing this work. Work Authorizations associated with the construction, installation and commissioning, production and abandonment phases of a project will not be granted until the applicant's Development Plan has received approval from the C-NSOPB/C-NOPB. The DA and its supporting documentation is also reviewed by the appropriate federal and provincial agencies.

Once the C-NSOPB/C-NOPB completes an adequacy review of the DA (and reviews any required DA Supplemental Report), the DA is provided to a Public Review Commission (or panel). The Commission reviews the DA and holds a public review of the DA and may request additional information based on Commission review and comments received from public. The Additional Information Document is also reviewed by the Commission and made available to the public. The Commission then posts a Public Notice of Agenda of Public Hearings, 30 days in advance of initiating public hearings (which can last one to three weeks). At the completion of the hearings, the Commission prepares a Recommendation Report to C-NSOPB/C-NOPB, which in turn prepares a Decision Report (which will include both the Commission's recommendations and the C-NSOPB's/C-NOPB's Conditions of Approval).

2.3.2.2 Development Approval

Once the C-NSOPB/C-NOPB has fulfilled their role in the project approvals process, their primary mandate is to oversee the operation and safety of the developments. There are several Regulations and Guidelines which oversee the way a development proceeds, including:

- *Nova Scotia Offshore Area Petroleum Geophysical Operation Regulations/Newfoundland Offshore Area Petroleum Geophysical Operations Regulations*;
- *Nova Scotia Certificate of Fitness Regulations/Newfoundland Offshore Certificate of Fitness Regulations*;
- *Nova Scotia Offshore Area Petroleum Diving Regulations/Newfoundland Offshore Area Petroleum Diving Regulations*;
- *Nova Scotia Offshore Area Petroleum Production and Conservation Regulations/Newfoundland Offshore Area Petroleum Production and Conservation Regulations*;
- *Nova Scotia Offshore Petroleum Drilling Regulations/Newfoundland Offshore Petroleum Drilling*

Regulations;

- *Nova Scotia Offshore Petroleum Installations Regulations*/*Newfoundland Offshore Petroleum Installations Regulations*;
- *Regulations Respecting Oil and Gas Operations in the Nova Scotia Offshore Area*/*Newfoundland Offshore Area Oil and Gas Operations Regulations*;
- *Canada-Nova Scotia Oil and Gas Spills and Debris Liability Requirements Regulations/Canada-Newfoundland Oil and Gas Spills and Debris Liability Regulations*;
- *Newfoundland Offshore Area Registration Regulations* (Newfoundland only);
- *Hibernia Offshore Development Project Offshore Applications Regulations* (Newfoundland only);
- *Hibernia Development Project Act* (Newfoundland only);
- Guidelines Respecting Drilling Programs in the Nova Scotia Offshore Area/Guidelines Respecting Drilling Programs in the Newfoundland Offshore Area;
- Guidelines Respecting Financial Responsibility Requirements for Work or Activity in the Newfoundland and Nova Scotia Offshore areas;
- Offshore Chemical selection Guidelines;
- CNSOPB/CNOPB Joint Guideline-Data Acquisition and Reporting for Well, Pool and Field Evaluations;
- Offshore Waste Treatment Guidelines (joint C-NOPB/C-NSOPB and NEB 1996 report, currently under review);
- Guidelines for Plans and Authorizations Required for Development Projects (C-NSOPB)/Development Application Guidelines (C-NOPB);
- Operator's Safety Plan (C-NSOPB)/Safety Plan Guidelines (C-NOPB);
- Geophysical and Geological Programs in the Nova Scotia Offshore Area-Guidelines for Work Programs, Authorizations and Reports/Geophysical, Geological, Environmental and Geotechnical Program Guidelines (C-NOPB);
- Industrial Benefits and Employment Plan - Nova Scotia Offshore Area (C-NSOPB);
- Respecting Physical Environment Programs during Petroleum Drilling and Production Activities on Frontier Lands (C-NSOPB);
- Issuance of Exploration Licenses (C-NSOPB);
- Guidelines Respecting Monthly Production Reporting for Producing Fields in the Newfoundland Offshore Area (C-NOPB);
- The Newfoundland Offshore Area Registration System Guidelines (C-NOPB);
- Newfoundland Offshore Area Guidelines for Drilling Equipment (C-NOPB); and
- Field Evaluations in the Newfoundland Offshore Area (C-NOPB).

Offshore development also requires the following approvals from the C-NSOPB/C-NOPB:

- Geotechnical/Engineering/Environmental Program Authorization;
- Declaration of Commercial Discovery;

- Production License;
- Operating License;
- Authorization to Install Production Installation;
- Drilling Program Authorization;
- Certificate of Fitness issued by a Certifying Authority and required by the
  - drilling unit prior to the issuance of a Drilling Program Authorization,
  - diving program prior to the issuance of a Diving Program Authorization,
  - production facility prior to the issuance of a Production Operations Authorization;
- Approval to Drill a Well;
- Production Operations Authorization;
- Diving Program Authorization; and
- Abandonment Program Authorization.

An offshore development would also be required to provide monthly accident statistics and well termination records, and applications for any variance from issued permits.

Other applicable regulations include the *Petroleum Occupational Safety and Health Regulations* (NS, Draft 1990)/Draft *Newfoundland Petroleum Occupational Safety and Health (OSH) Regulations* and the *Canada Oil and Gas Operations Regulation*.

2.3.3 Joint Offshore Board/Canadian Environmental Assessment Act Process

2.3.3.1 Project Approval

The development of offshore oil and gas projects is subject to the *Canadian Environmental Assessment Act* (*CEAA*).

Responsible Authorities

C-NSOPB/C-NOPB
In Atlantic Canada, the C-NOPB must issue a production license 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 land…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. It is not clear whether the land trigger applies under C-NSOPB's jurisdiction. In the absence of a Board which represents the federal and provincial government, it is most likely that the NEB would act as Lead Responsible Authority (an application to construct and operate a pipeline under Section 52 of the *National Energy Board Act* is a trigger under *CEAA*), given the likelihood that pipelines would be constructed to transport gas from the offshore.

Department of Fisheries and Oceans

If a proposed project is determined by DFO to result in the harmful alteration, disruption or destruction (HADD) of fish habitat, an Authorization for Works or Undertakings Affecting Fish Habitat under Section 35(2) of the *Fisheries Act* is required. As Section 35(2) authorization is a Law List trigger under *CEAA*, DFO will also be a Responsible Authority with respect to the environmental assessment of the project. Further, as a condition of this authorization, a developer is 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. Given the importance DFO places on HADD and compensating for a HADD determination, a brief overview of the HADD compensation process is provided in Appendix 2.

Environment Canada

Environment Canada determined both for Terra Nova and White Rose projects 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 Environment Canada is a Responsible Authority. If an offshore development intends to use glory holes, or is burying/trenching pipelines, Environment Canada would be a Responsibility Authority.

Industry Canada

Industry Canada has determined for White Rose 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, is also a Responsible Authority respecting the proposed project. It is very likely that Industry Canada will be a Responsible Authority for any offshore development that conducts radio communication.

DFO-Canadian Coast Guard

An approval may be required under the *Navigable Waters Protection Act* (*NWPA*) (DFO-Canadian Coast Guard) in cases where proposed development activities have the potential to interfere with navigable waters (this is usually limited to 12 nautical miles from shore). In the event there is a nearshore/onshore section of pipeline, there would be a trigger under the *NWPA*, and therefore, DFO-Canadian Coast Guard would also be a Responsible Authority.

Process

Offshore development falls within the *Comprehensive Study List Regulations*, Part IV, Oil and Gas Projects, Section 11. The lead Responsible Authority is designated from among the Responsible Authorities, and is responsible for coordinating the government and public review.

The submission of a project description document serves the purpose of project referral to federal authorities pursuant to *CEAA*. Because of the regulatory overlap between the Accord Acts and *CEAA* with respect to environmental protection, the respective processes may be harmonized with respect to fulfilling information requirements of both processes (or three, if the NEB is involved, as is the case if a development includes the construction and operation of a pipeline).

The review of a Comprehensive Study can be conducted concurrently or in advance of the DA (as was the case with the White Rose DA) (However, the Commission's Notice of Agenda for Public Hearings (see Section 2.2.2.1) cannot be published until the federal Minister of Environment has released the project from *CEAA*).

2.3.3.2 Development Approval

Prior to the construction and operation of a development, other federal authorizations, permits and licenses must be acquired exclusive of release from *CEAA*. The primary approvals are:

- HADD Authorization (note that HADD must be quantified and a Habitat Compensation Strategy provided to DFO prior to release from *CEAA*) – the HADD Authorization can be negotiated with DFO concurrently with the DA Approval process (in anticipation of release from the DA process and approval to proceed with the project), but must be in place prior to any disturbance of the substrate (see Appendix 2);
- Ocean Disposal Permit – an Ocean Disposal/Disposal at Sea Permit application can be forwarded to Environment Canada concurrently with the DA Approval process (in anticipation of release from the DA process and approval to proceed with the project), but must be in place prior to an displacement of the substrate; and
- Radio License – a Radio License application can be forwarded to Industry Canada once approval to proceed with the project is provided, but prior to the installation of the production facility.

2.3.4 Joint National Energy Board/*Canadian Environmental Assessment Act*/Board Process

2.3.4.1 Project Approval

If a pipeline (>40 km) is required, then *CEAA* is triggered by the application for a Certificate of Public Convenience and Necessity (currently, only Nova Scotia has export pipelines from offshore gas developments). In that case, the NEB would act as a Responsible Authority and provide input into the issues scoping package, provide comment on a filed Comprehensive Study and sign-off on a Comprehensive Study Report (which may be delegated to the proponent to prepare). Any public hearings (NEB requires public hearings for pipelines >40 km in length) could be coordinated between the NEB and the C-NSOPB or other Board.

The Responsible Authorities, which sign-off on the Comprehensive Study, must respond to any recommendations made by the Public Hearings Commission, with the approval of the Governor in Council (GIC). If the Comprehensive Study, and therefore, the application for a Certificate of Public

Convenience and Necessity, is released from *CEAA*, the application would then complete the NEB regulatory process, as described in Section 2.1.

2.3.4.2 Development Approval

Once the pipeline has been approved and undergone the required testing, the proponent must file an application for leave to open the pipeline from the NEB.

2.3.5 Other Approval Processes

2.3.5.1 Nova Scotia Utility and Review Board Approval Process

The construction and operation of a pipeline on Nova Scotia lands (which includes the offshore) requires authorization from the Nova Scotia Utility and Review Board (NSUARB) (ACPI and Erlandson & Associates 2001a), pursuant to the *Pipeline Act*. Specifically:

- permits to construct a pipeline; and
- license to operate a pipeline.

NSUARB only gets involved with onshore and offshore pipeline permitting that is not NEB regulated (*i.e.,* liquid lines that are not tied into a NEB-regulated transmission system (e.g., Maritimes and Northeast Pipeline) or do not otherwise cross inter-provincial boundaries).

2.3.5.2 Other Nova Scotia Regulatory Agencies

Several provincial regulatory agencies have signed Memoranda of Understanding (MOU) with the C-NSOPB, which allows these agencies the ability to address issues arising from overlapping jurisdictions. These include (ACPI and Erlandson & Associates 2001a) the:

- Nova Scotia Department of Environment and Labour;
- Nova Scotia Department of Natural Resources; and
- Energy Resources Conservation Board.

The Nova Scotia Petroleum Directorate has direct responsibility for administering the offshore royalty regime and is directly involved with providing the C-NSOPB with advice on a number of issues, including benefits. It also has MOU with other provincial regulatory agencies and provides a one-window process as the primary means of promoting consultation and communication among the agencies (ACPI and Erlandson & Associates 2001a).

The Nova Scotia Department of Fisheries and Aquaculture is a member of the C-NSOPB Fisheries and Environmental Advisory Committee. The Office of Aboriginal Affairs in Nova Scotia does not exercise regulatory functions in offshore Nova Scotia; however, it is currently in discussions which might affect offshore oil and gas development as a result of recent court cases initiated by aboriginal communities (ACPI and Erlandson & Associates 2001a).

2.3.5.3 Other Newfoundland Regulatory Agencies

The Newfoundland and Labrador Department of Mines and Energy enacts legislation and regulations similar to the Newfoundland Accord Acts for offshore areas. In conjunction with the federal Minister of Natural Resources, the Minister of Mines and Energy is responsible for issuing directives to the C-NOPB and reviewing fundamental decisions issued by the C-NOPB (ACPI and Erlandson & Associates 2001b).

Several provincial regulatory agencies have signed MOU with the C-NOPB, which allows these agencies the ability to address issues arising from overlapping jurisdictions. These include (ACPI and Erlandson & Associates 2001b) the:

- Newfoundland and Labrador Department of Environment (recognized as the principal advisor to the C-NOPB);
- Newfoundland and Labrador Department of Labour; and
- Newfoundland and Labrador Department of Fisheries and Aquaculture.

2.3.5.4 Shore-based Facilities

It should be noted that if any shore-based facilities need to be constructed specifically for an offshore project, then those facilities may also be subject to *CEAA* and/or the relevant provincial authority. It is assumed that the potential effects of construction and operation of shore-based facilities would be assessed under the British Columbia *Environmental Assessment Act* (refer to Section 2.2).

2.3.6 Lessons Learned

Based on the recent experience with the White Rose development (and previous environmental assessments), the following are key lessons learned about the Atlantic Canada regulatory process:

- the Comprehensive Study required by *CEAA* can fulfill the EIS/SEIS requirements of the C-NSOPB/C-NOPB;
- the release of the project from *CEAA* triggers the public review under the Accord Acts (*i.e.,* the Notice of Agenda for the public hearings may not be made public until the federal Minister of Environment has released the Comprehensive Study from *CEAA*);
- liaison with stakeholders is key to the success of the project, including
  - early meetings with regulators to identify key issues, and
  - early public meetings (prior to the formal process) to both provide information to communities and stakeholders and to solicit comments and issues of concern;
- upon delivery of the environmental assessment document, a meeting for all regulators is advised to

present findings to assist regulators in their review of the document and provide clarification of any aspects of the environmental assessment; and

- early clarification of the internal regulatory review process due to harmonized nature of the various approvals processes is essential.

3.0 REGIONAL SETTING

The experience of the US Minerals Management Service (MMS) and other non-petroleum industries (such as the Voisey's Bay Nickel Company Limited Mine/Mill EIS) indicates that traditional First Nations knowledge of the biological resources of an area should be incorporated into any formal assessment of a project. The process of gathering the information should be a formalized agreement with the First Nations communities.

3.1 Marine Coastal Biodiversity/Continental Shelf Biota

3.1.1 Ecosystems

The report and recommendations of the 1986 West Coast Offshore Exploration Environmental Assessment Panel describes the biophysical environment within the region of interest. The majority of this information remains valid in terms of overall ecosystems, species, and fisheries. Some changes have occurred, however, primarily related to species stocks and harvesting operations.

The two major marine ecosystems in BC are the nearshore and continental shelf ecosystems. The main factor influencing the differences in these two ecosystems is depth. Where the nearshore ecosystem occurs in shallow waters near rocky shores, estuaries, mud flats and shallow bays, the continental shelf exists in deeper waters off shore. Because the nearshore waters are shallow, light penetrates the water, allowing vegetation such as kelp and algae to grow and become the primary producers in the ecosystem. In the continental shelf ecosystem, phytoplankton is the primary producer.

A significant feature of the continental shelf ecosystem in BC is the deep-water sponge reefs. These sponge reefs are the only known Hexactinellid sponge reefs living in the world today. They cover approximately 1,000 km^2 between the Queen Charlotte Islands and the mainland and are believed to be nearly 10,000 years old (GSC 2001). Evidence of damage to these reefs by trawling gear has created concern for the protection of these reefs.

3.1.2 Finfish and Shellfish

The stocks of many species of fish have changed since the 1986 report. Species such as Pacific halibut, petrale sole, yellowtail rockfish*, rock sole and English sole have been declining as a result of declining recruitment and Pacific hake stocks have been declining since the late 1980s, returning to historic, typical levels. Pacific cod have declined until 1996, when it experienced a slight increase to 1998 but* *was expected to decline in the subsequent two years. Rockfishes such as redstripe and redeye have* increased until 1995, but abundance is expected to decline until the next major recruitment. Herring stocks have increased since 1986, but are expected to decline again in the long term (DFO 2001a; 2001b; 2001c).

Pacific invertebrate fisheries are diverse. Geoducks and intertidal clams have had quotas reduced since 1987 and the Pacific abalone fishery has been closed for most of the 1990's due to low stocks. Restrictions were placed on the BC shrimp fishery in 1997 and crab landings also declined after 1996 due to reduced stocks (BC Statistics May 2001).

Since 1986, steelhead have been re-classified as a Pacific salmon (Oncorhynchus mykiss), thus making six species of salmon caught by commercial, recreational, and aboriginal fishers in British Columbia. The other five are: sockeye, pink, chum, coho, and chinook.

Sockeye and pink salmon were once the most abundant of the Pacific salmon species. Returns of Sockeye and pink salmon were at record high levels through the 1980's and the early part of the 1990s. However, more recently, returns have decreased due to extreme fluctuations in marine survival. For example, in 1995, returns of Fraser River sockeye were well below predicted levels, even though the spawning escapement in the parent year was the highest ever recorded for this cycle.

Chum salmon catches in British Columbia appear to be highly variable and dependent on recruitment and environmental conditions.

Chinook and coho salmon are highly valued by all fishers. However, marine survival rates for the 1990s have generally been low. Some runs of chinook salmon, such as those along the west coast of Vancouver Island and some parts of the Strait of Georgia, have had severe conservation measures put in place due to protect low stock levels. Coho salmon stocks have also had low returns in the Strait of Georgia and in the upper Skeena River watershed and management measures were taken in 1995 to reduce the harvest rates on Strait of Georgia coho stocks. Since the late 1990s, there has been no commercial fishery for coho salmon. *Habitat degradation has also become a concern for Strait of Georgia coho, as human populations expand and demand for residential, commercial and recreational development increases.*

3.1.3 Seabirds

The Canadian Wildlife Service (CWS) has conducted a comprehensive inventory of colonial nesting seabird populations in British Columbia since 1986 (Rodway et al. 1988) and an overview of the historical and current information regarding seabird colony distributions and breeding populations has also been conducted (Rodway 1991). In general, over 5.6 million colonial birds are currently estimated to nest at 503 colony sites along the British Columbia coast (Rodway 1991). Most populations breed in high-density colonies which may contain various seabird species. In addition to the work being done by *the CWS, the United States Fish and Wildlife Service (USFWS) has a seabird colony database and the United States Geographic Service (USGS) have a Pacific Seabird Monitoring database. The Pacific Seabird Monitoring database includes colonies in British Columbia, however, at this time, it consists mostly of raw observations and is therefore not available to the public.*

Fifteen species of seabirds are known to breed on the coast of British Columbia (Table 3.1).

Table 3.1 Status of Seabird in British Columbia and their Distribution

Species	Estimated Numbers	Status	Distribution
Fork-tailed Storm Petrel (Oceanodroma furcata)	400,000	Trends unknown, believed healthy	*Colonies on the Storm Islands in Queen Charlotte Strait and on Gillam Islands on the west coast of Vancouver Island support approximately 49 percent of the total provincial population.*
Leach's Storm Petrel (Oceanodroma leucorhoa)	1,400,000	Trends unknown; believed healthy	*A cluster of four colonies in Queen Charlotte Strait, plus two colonies on the west coast of Vancouver Island contain approximately 74 percent of the total population found an British Columbia's coast.*
Double-crested Cormorant (Phalacrocorax auritus)	4,000	Blue-listed	*Generally confined to the Strait of Georgia where numbers have increased dramatically since they were first recorded. Estimates in 1991 gave a total of over 2,000 nesting pairs in the Strait of Georgia area.*
Brandt's Cormorant (Phalacrocorax pencillatus)	200	Red-listed	*Nesting in small numbers on Sea-lion Rocks off the mid-west coast of Vancouver Island, the maximum numbers recorded up to 1991 was 150 nesting pairs in 1970.*
Pelagic Cormorant (Phalacrocorax pelagicus)	9,000	*pelagicus* subspecies red-listed; other subspecies stable	*Although they breed along the entire coastline, most of the nesting population occurs in the south on the east and west sides of Vancouver Island. An estimated 4,495 pairs were breeding at 85 sites in 1991, with 52 percent of the population nesting in the Strait of Georgia and 26 percent along the west coast of Vancouver Island.*
Glaucous-winged Gull (Larus glaucenscens)	58,000	Increasing	*These gulls have a similar distribution to that of pelagic cormorants. It was estimated that 28,953 pairs bred along the coast in 1991, with 48 percent of the total population nesting in the Strait of Georgia and 25 percent on the west coast of Vancouver Island. Data suggests that populations increased by as much as 30 percent in the Queen Charlotte Islands and by 48 percent along the northern mainland coast from 1975-1988.*

Species	Estimated Numbers	Status	Distribution
Common Murre (Uria aalge)	9,000	Red-listed	*The colony at Triangle Island is thought to support 95 percent of the breeding population (4,100 pairs in 1989).*
Thick-billed Murre (Uria lomvia),	20	Red-listed	*Known to breed on Triangle Island, which is the southern most known breeding site in the eastern Pacific.*
Pigeon Guillemot (Cepphus columba)	9,000	Trends unknown	*The most ubiquitous breeding alcid in the province, nesting at an estimated 303 sites. A total of 9,345 birds were counted around colonies during the 1991 surveys.*
Marbled Murrelet (Brachyramphus marmoratus)	36,000	Threatened (COSEWIC); red-listed	*Known to inhabit Desolation Sound.*
Ancient Murrelet (Synthliboramphus antiquus),	540,000	Vulnerable (COSEWIC); blue-listed	*Generally known to breed exclusively on the Queen Charlotte Islands where estimates have been as high as 543,000 birds. These numbers were probably higher in the past as current trends in population numbers show declines and colony abandonments. In 1991, British Columbia supported approximately 74 percent of the world breeding population.*
Cassin's Auklet (Ptychoramphus aleuticus),	2,700,000	Blue-listed	*The most abundant breeding species in British Columbia, their population is estimated to be over 2.7 million nesting at 60 sites. 73 percent of the population breed at 3 sites in the Scott Island and the rest breed in the Queen Charlotte I.*
Rhinoceros Auklet (Cerorhinca monocerata)	720,000	Stable	*Over 720,000 breed in British Columbia at over 30 sites. This represented approximately 56 percent of the world breeding population in 1991. Most are found on two colonies in Queen Charlotte Strait, four colonies on the northern mainland coast and one colony in the Scott Islands*
Tufted Puffin (Fratercula cirrhata)	78,000	Blue-listed	*Over 90 percent of the 78,000 breeding in British Columbia nest in the Scott Islands. Small numbers also breed throughout the coastline.*
Horned Puffin (Fratercula corniculata)	60	Red-listed	*Their summer range appear to be expanding along the west coast of North America. They have been confirmed nesting in British Columbia only at Anthony Island at the south end of the Queen Charlotte Islands*

Source: Rodway 1991; Environment Canada 2000

3.1.4 Marine Mammals

There are 29 species of marine mammals along coastal BC (Ministry of Forests 1995). Of these 29 species, only eight are commonly seen. These include porpoises, dolphins, seals, sea lions, otter and mink (WCOEEAP 1986). There are three marine mammals on the provincial red-list, meaning they are extirpated, endangered or threatened in British Columbia. The three species on the red-list are northern right whale (*Eubalaena glacialis*), northern sea lion (*Eumetopias jubatus*) and sea otter (*Enhydra lutris*). The BC Conservation Data Centre lists 10 species of marine mammals and three populations as vulnerable: northern fur seal (*Callorhinus ursinus*), Bering Sea beaked whale (*Mesoplodon stejnegeri*), arch-beaked whale (*Meloplodon carlhubbsi*), sperm whale (*Physeter catodon*), harbour porpoise (*Phocoena phocoena*), grey whale (*Eschrichtius robustus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), blue whale (*Balenoptera musculus*), humpback whale (*Megaptera novaeangliae*) and the Northeast Pacific Resident, Northeast Pacific Offshore and West Coast Transient populations of killer whale (*Orcinus orca*) (BC CDC 2001).

Grey whales are the first great whale to be removed from the endangered species list. As populations recover, more animals are returning to their historical British Columbia range to feed on mysid shrimp.

Research initiatives, such as the Coastal Ecosystems Research Foundation (CERF), have been conducting ongoing research on whales and dolphins on the coast of BC*. Relevant research includes grey whale toxicology. Heavy metal and PCB levels in mysid shrimp populations, primary prey for grey whales, are being studied.*

The Pacific white-sided dolphin is one of the most abundant cetaceans in the North Pacific, and in recent years, it has been sighted more frequently and in larger numbers in the inshore waters of British Columbia. Humpback whales have also been gradually returning to their original habitats, including Queen Charlotte Sound.

3.2 Commercial Fishery

During the 1990s, the number of fish processing plants has declined in British Columbia. Some of this decline was due, in part, by the industry consolidation. In 1990, there were 219 provincially licensed fish processing plants. By 1999, this number had decreased 13 percent to 190. Most of the reduction in plants was focused on Vancouver Island and the Sunshine Coast, where 28 and 10 plants, respectively, were shut down during the 1990s. The one area of the province with considerable growth during the 1990s was the North Coast, which experienced a 36 percent increase in fish processing facilities (BC Statistics May 2001).

Although there was a decline in commercial landings for wild salmon during the 1990s (Section 3.2.1), the export values of BC fish increased 10 percent from $773 million in 1990 to $853 million in 1999 (BC Statistics May 2001).

3.2.1 Salmon

Landed catch by tonne for all species of salmon has continually decreased between 1986 *and* 1999*.*

Statistical information is not yet available for 2000 and 2001. In British Columbia, *the catch has decreased* from 103,780 tonnes in 1986 to 96,400 tonnes in 1990 to 19,900 tonnes in 1999. Landings for pink salmon decreased 66 percent between 1986 and 1999, from approximately 29,505 tonnes to approximately 10,000 tonnes. Chum landings dropped 80 percent between 1986 and 1999 (approximately 25,197 tonnes and 5,000 tonnes, respectively). Chinook landings decreased 80 percent from 5,007 tonnes in 1986 to less than 1,000 tonnes in 1999. Of the five species of Pacific salmon, sockeye landings have fluctuated the most, however, the overall trend has resulted in a 95 percent decrease between 1986 and 1991 (approximately 30,833 and 1,800 tonnes, respectively). Because of the threat to wild coho stocks, restrictions were placed on the commercial fishery in 1996 and became progressively more severe, until there were no commercial landings of coho in 1999.

As a result of the decrease in landed catch for Pacific salmon, landed values have decreased 46 percent between 1986 and 1999. Landed values for wild salmon were approximately $265 million in 1986 and fell to approximately $170 million in 1999 (BC Statistics 2000; 2001).

3.2.2 Herring

In BC, the total herring catch by tonne, including herring spawn on kelp, increased from 1986 to 1994 (16,491 to 40,902 tonnes, respectfully), but dropped significantly in the intervening five years to 29,800 tonnes in 1999. The majority of herring is caught on the North Coast and although the landed value increased despite the down turn until 1996 ($46,209,000 to $99,700,000), it declined to approximately $50,000,000 in 1999 (BC Statistics 2000; 2001).

3.2.3 Halibut

The halibut catch by tonne in British Columbia has fluctuated only slightly since 1986. In 1996, the catch was slightly above the 1986 level (5,389 and 5,431 tonnes, respectfully) (BC Statistics 2000). In 1999, the catch was 5,500 tonnes. The majority of halibut is landed on the North Coast. Its value has increased from $24,455,000 in 1986 to $39,000,000 in 1999 (BC Statistics May 2001).

3.2.4 Groundfish

Groundfish landings have fluctuated considerably during the 1990s, however, in 1999, the landed catch for groundfish was 139,000 tonnes, which is virtually the same as the 1990 catch. During the 1990s, hake was the dominant species landed, standing at 57 percent in 1990 and 67 percent in 1999. Rockfish increased slightly from 16 percent of the harvest in 1990 to 17percent in 1999. Sole and sablefish landings decreased slightly from 4 to 3 percent. Due to the declining stocks of Pacific cod, restrictions were placed on the harvest in 1992, resulting in a decline in landed catch from 5 percent in 1990 to 1 percent in 1999 (BC Statistics May 2001).

Landed value for groundfish increased from $67 million in 1990 to $100 million in 1999 (BC Statistics May 2001).

3.2.5 Shellfish

The commercial harvest of shellfish had a dramatic increase in 1992, rising from 21,500 tonnes in 1990 to 31,500 tonnes in 1992. Landings then dropped to 24,000 tonnes in 1999. This high level of fluctuation was due to the increase in wild sea urchin landings in 1992 and the introduction of quota and area restrictions, in particular on the BC shrimp trawl fishery in 1997 (BC Statistics May 2001).

The BC shellfish fishery harvests many different species of invertebrates, however, in 1999, the largest landings were for sea urchin (6,800 tonnes), shrimp and prawns (5,200 tonnes) and crab (3,900 tonnes). Both sea urchin and shrimp harvests briefly increased in the 1990s and then decreased following restrictions put in place to protect declining stocks. The harvest of crab increased at the beginning of the decade and then declined after 1996 following management restrictions and reduced stocks. Landings for wild geoducks declined over the 1990s (approximately 4,000 tonnes in 1990 to 1,500 tonnes in 1999) due to management restrictions (BC Statistics May 2001).

3.2.6 Commercial Sport Fishery

Sport fishing continues to be an important recreational activity for both residents and non-residents of British Columbia. It is the largest industry in the fisheries and aquaculture sector in BC, with a total GDP of $214 million in 1999. The sport fishing industry had been growing up until the mid-1990s. However, it is showing the effects of the uncertainty in salmon stocks and restrictions for resource conservation measures (BC Statistics June 2001).

3.2.7 Aquaculture

Farmed salmon is the primary aquaculture species in British Columbia. *Landed tonnes and value are not available from 1986* but have generally increased during the 1990's. In 1990, 15,500 tonnes of production from salmon aquaculture operations were worth $79 million. By 1990, this increased to 49,100 tonnes worth $292 million. Before 1993, the main salmon species farmed was chinook, but by 1993, Atlantic salmon had become the number one farmed species in BC (BC Statistics May 2001).

The salmon aquaculture industry has substantially reduced in size between the mid-1980's and the mid-1990's. There are presently sixteen salmon farming companies operating in British Columbia at seventy-nine locations. A provincial government moratorium on the issuance of new tenures has been in effect since 1995, although in 1996, several tenures whose applications had been pending for some time were issued. Salmon farming sites are typically less than 10 ha in size with a less than 200 hectares of aquatic Crown land presently allocated for salmon aquaculture purposes. The locations (by regional District) of existing salmon farm site tenures in British Columbia, including inactive tenures, as of 1996 are shown in Table 3.2.

Table 3.2 Distribution of Active Grow-Out Sites by Regional District

Regional District	1996
Alberni-Clayoquot	18
Comox-Strathcona	28
Mount Waddington	21
Nanaimo, Cowichan, Capital	8
Sunshine Coast & Powell River	4

Source: www.eao.gov.bc.ca/PROJECT/AQUACULT/SALMON/Report/final/vol1/V1chp2.htm

3.3 First Nations

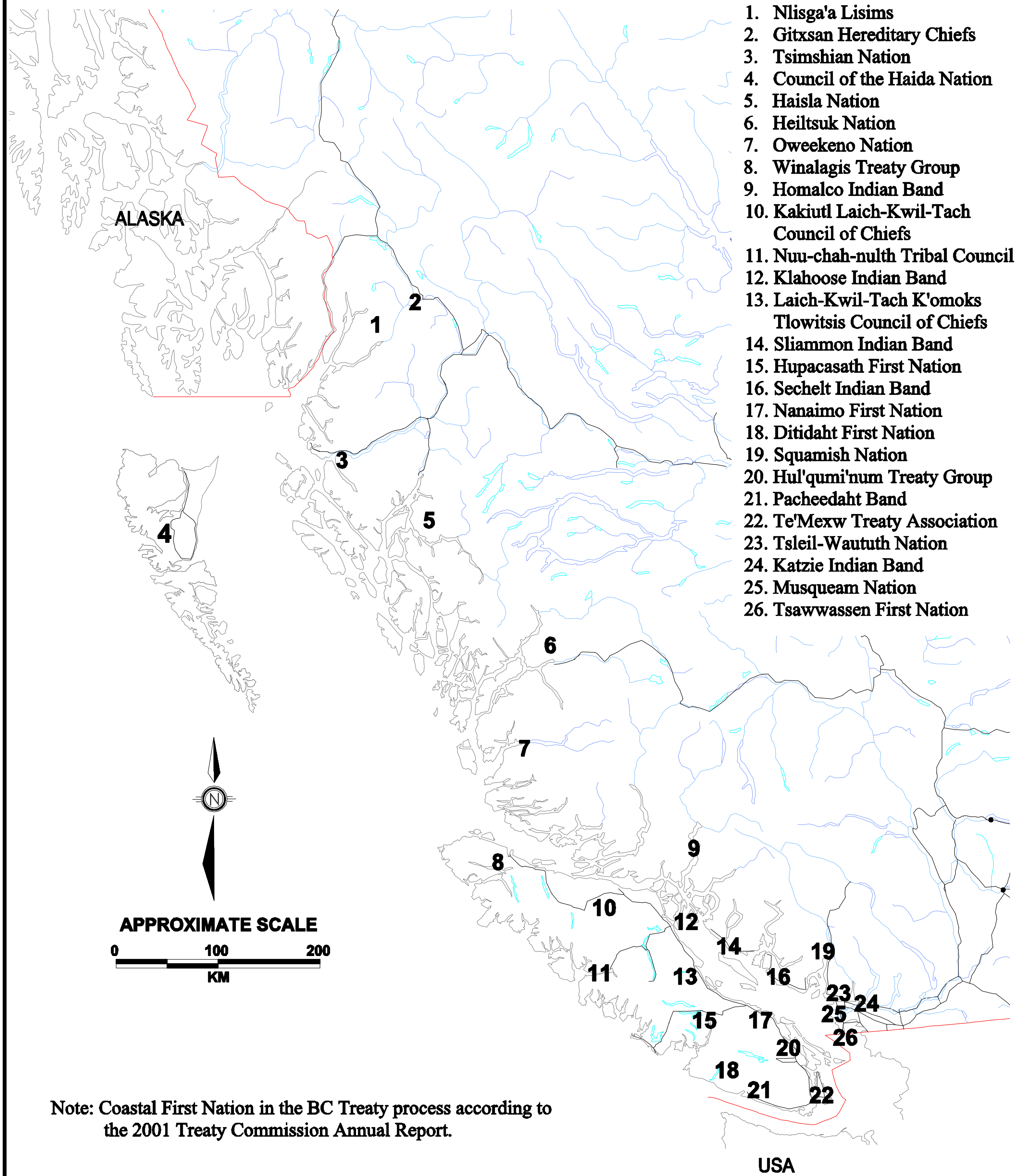
The asserted traditional territories of a number of culturally and linguistically distinct First Nations are situated on the northern Vancouver Island, central coast and north coast areas of British Columbia within the subject area under review. The Haida (the Council of Haida Nations) are situated on the Queen Charlotte Islands (Haida Gwaii) the Nisga'a (Nisga'a Lisims Government) at the mouth of the Nass River and in the Nass Valley. The Tsimishian First Nations (Tsimshian Tribal Council), Haisla Nation, and Heiltsuk First Nation are situated on the north and central coast and the Winalagalis Treaty Group, Kwaguilth First Nations on northern Vancouver Island and the south central coast. To the south of the area of review are the Nuu-chah-nulth First Nations (Nuu-chah-nulth Tribal Council) located on the west coast of Vancouver Island and the Coast Salish First Nations of the Georgia Basin watershed south of Powell River (Sliammon First Nation).

As a result of the signing of the BC Treaty Commission Agreement on September 21, 1992, tripartite negotiations are underway for most Coastal First Nations through the six stage B.C treaty process. The BC Treaty Commission’s 2001 Annual Report indicates that province-wide there are 49 First Nations in 40 sets of negotiations in the treaty process. The Council of the Haida Nation is in stage 2, The Nisga'a have completed their Final Agreement and 42 First Nations are at stage 4 including the Tsimshian Nation, the Haisla Nation, the Heiltsuk Nation, the Nuu-chah-nulth Nation, and the Winalagalis Treaty Group. These latter First Nations have asserted traditional territories in the area of review. There are additional First Nations that are not participating in the treaty process that may overlap with the area of interest.

The distribution map on Figure 3.1 shows relative locations for the coastal First Nations that are currently participating in the British Columbia treaty process.

3.3.1 Populations

Population numbers for the central and north coastal First Nations communities, as of month ending September 2001, indicate that there are approximately 28,500 people affiliated with these First Nations. These statistics, from Indian and Northern Affairs Canada, British Columbia Region, include population on reserve and off reserve for each community and are presented in Table 3.3 below.



Note: Coastal First Nation in the BC Treaty process according to the 2001 Treaty Commission Annual Report.

COASTAL FIRST NATIONS IN THE BC TREATY PROCESS OFFSHORE OIL AND GAS TECHNOLOGY UPDATE BC MINISTRY OF ENERGY AND MINES	DATE: OCTOBER 19, 2001	SCALE: AS SHOWN	Jacques Whitford
	JOB No. BCV 50229	FIGURE No. 3.1	

In reviewing the population statistics by residence code presented below, the residence codes are as follows: 1 = on reserve (own band), 2 = on reserve (other band), 3 = on crown land (own band), 4 = on crown land (other band), 5 = on crown land (no band), and 6 = off reserve.

Table 3.3 Populations of Central and North Coast First Nations in the BC Treaty Process

First Nation	Affiliated Bands	Population by Residence Code						
		1	*2*	*3*	*4*	*5*	*6*	*Total*
Gitxsan Hereditary Chiefs	Gitanmaax	714	100	0	0	0	1062	1876
	Gitsegukla	490	30	0	0	0	299	819
	Gitwangak	456	29	0	0	0	507	992
	Glen Vowel/Sikokoak	153	27	0	0	0	175	355
	Kispiox	642	72	0	0	0	619	1333
Tsimshian Nation	Hartley Bay	170	12	1	0	0	447	630
	Kitasoo	320	8	0	0	0	143	471
	Kitkatla	431	18	0	0	0	1125	1574
	Kitselas	193	11	0	0	0	265	469
	Kitsumkalum	191	9	0	0	0	404	604
	Lax Kw'alaams	1076	42	0	0	1	1629	2748
	Metlakatla	105	2	0	0	0	593	700
Council of the Haida Nation	Old Massett Village Council	733	33	0	0	0	1677	2443
	Skidegate	694	6	0	0	0	542	1242
Heiltsuk Nation		1189	39	0	0	0	841	2069
Oweekeno Nation		97	12	0	0	0	126	235
Winalagalis Treaty Group	Kwakiutl	325	11	0	0	0	264	600
	Tlatlasikwala	8	8	0	0	16	14	46
	Namgis	738	28	0	0	0	724	1490
	Quatsino	211	4	0	0	0	151	366
	Gwa'Sala-Nakwaxda'xw	406	7	0	0	0	248	661
Homalco		221	6	0	0	0	191	418
Hul'qumi'num Treaty Group	Chemainus	751	65	0	0	0	209	1025
	Cowichan	1777	213	0	0	0	1565	3555
	Halalt	84	13	0	0	0	92	189
	Lake Cowichan First Nation	12	0	0	0	0	2	14
	Lyackson	12	21	0	0	0	138	171
	Penelakut	465	26	0	0	0	266	757
Pacheedaht First Nation		101	16	0	0	0	128	245
Tlowitsis Council of Chiefs		11	35	0	0	63	233	342
Totals		**12,776**	**903**	**1**	**0**	**80**	**14,679**	**28,439**

Source: INAC – BC Registered Indian Population

3.3.2 Position Statements

Significant changes have occurred since the *Report and Recommendations of the West Coast Offshore Exploration Environmental Assessment* of 1986 that have led to greater involvement of First Nations in the management of natural resources within their traditional territories. These changes include a series of Supreme Court of Canada decisions, Guerin (1984), Sparrow (1990), and Delegamuukw (1993, 1997), creation of the British Columbia Treaty Commission Agreement in 1992, and the Nisga'a Final Agreement, now recognized under s35 of the *Constitution Act*. More recently, the Province of British Columbia has entered into two protocol agreements with many of the First Nations having traditional territories in the area of review for the offshore oil and gas moratorium. While these agreements do not address the offshore oil and gas issue they do move the signatory parties toward a greater role in natural resource management by addressing a series of process and forestry related objectives. The agreements also include mechanisms to consider and where possible to address ecological and environmental issues and other concerns and to develop a strategic land use plan with the Province.

A number of First Nations have issued formal and informal statements on the Moratorium on North Coast Oil and Gas Exploration. The Tsimshian and Haida nations issued a joint statement on the moratorium on May 14, 2001. This statement supports retention of the moratorium citing two primary reasons: “the petroleum interests…are within the territorial seas” of the two Nations; and, “the risk of harm from an accidental oil spill or allowable discharge is not acceptable”. In a speech at the conference “The Future of Offshore Oil and Gas Development in British Columbia” on October 2, 2001, Mr. Garry Reece, the elected Chief of the Lax kw’alaams Band, clearly stated the concerns of the Lax kw’alaams Band. These included possible negative environmental effects, risk of impacts to marine resources the Band relies upon and potential negative social risk to their culture that would result from large-scale industrial activity. Based on these considerations, the Lax kw’alaams Band is opposed to any change in the moratorium. However, Mr. Reece went on to state that the Band is willing to review its position subject to full and honest dialogue with proponents, leadership roles in studies reviewing the effects of oil and gas developments and opportunities to achieve economic benefits from any development. To ensure that these opinions are understood, the Tsimshian Haida Statement on the moratorium on North Coast Oil and Gas Exploration, the Heiltsuk position and a speech by Chief Gay Reece of the Lax Kw’alaams First Nation are attached as Appendix 2.

3.4 Communities

The potential for oil and gas exploration in Hecate Strait, as noted in the two previous reports (AGRA Earth and Environmental 1998 and Province of British Columbia 1986), could have significant benefits and / or impacts on local district centres of varying sizes. The following describes the state of the economy in many of the centres whose districts are adjacent to the current moratorium area. Specific reference is made to the communities, population, labourforce, and key economic sectors, including fisheries and tourism.

3.4.1 People

There are four districts identified by the provincial government, which border on the current exploration moratorium area. They are:

- Regional District 43: Mount Waddington;

- Regional District 45: Central Coast;
- Regional District 47: Skeena-Queen Charlotte; and
- Regional District 49: Kitimat-Stikine.

All districts have positive growth rates (under 1 percent per year, 10-year average) and labourforce participation rates higher than the provincial average. All districts have a significant public sector and forestry sector contribution to employment, while the mining and fishing and trapping sectors contribute less to district employment. By way of contrast, British Columbia's employment leaders are public sector (24 percent), forestry (20 percent), and tourism (7 percent).

Table 3.4 describes the income dependency by industry for the centres identified above. Income dependency refers to sector contribution to household income within the District. For comparison, provincial statistics are shown at the bottom.

Table 3.4 Income and Sector Dependency, Selected Centres

District	**Average Household Income**	**Income Dependency (1996)**	**Percentage Share**
District 43 - Mount Waddington	60,245		
		Forestry	45
		Public Sector	18
		Fishing/Trapping	7
		Tourism	6
District 45 - Central Coast	41,861		34
		Public Sector	22
		Forestry	8
		Tourism	7
		Fishing/Trapping	
District 47 - Skeena-Queen Charlotte	56,305		
		Public Sector	28
		Forestry	25
		Fishing/Trapping	13
		Tourism	8
District 49 - Kitimat-Stikine	57.636		
		Forestry	25
		Public Sector	24
		Mining	15
		Tourism	6
British Columbia	56,527		
		Public Sector	24
		Forestry	20
		Tourism	7
		Mining	5

Source: BC Stats

Table 3.5 below describes the population, growth rate, and labourforce participation rates of these Districts (including the largest centres for each Regional District).

Tourism (and ecotourism) in communities within the study is a growing industry, and is being encouraged in order to diversify a primary-producer and resource-extraction based economy, and to combat seasonal unemployment. Presently between 6-8 percent of residents are dependent on the tourism-based economy for household income.

Table 3.5 District Population Statistics

District	Largest Centres	Population (2000)	% District Growth Rate (10yr. Avg.)	Participation Rate (1996), %
43 - Mount Waddington	Port Hardy	5,228	0.3	77.5
45 - Central Coast*		4,556	1.8	71.6
47 - Skeena-Queen Charlotte	Prince Rupert	17,027	0.2	74.2
	Masset	1,266	-	-
49 - Kitimat-Stikine	Kitimat	11,533	1.1	70.8
Total, British Columbia		4,063,760	2.3	60

* Bella Coola 1996 population - 873
Source: BC Stats

3.4.1.1 Regional District 43 - Mount Waddington

Port Hardy is the largest centre in RD 43, with a population of 5,228, which accounts for approximately 35 percent of the region's population, though the land area is only 0.2 percent of the region. Port Hardy's economy has a high reliance on forestry and the primary resources sector of the economy and the participation rate is highest in the study area.

3.4.1.2 Regional District 45 - Central Coast

The Central Coast district has port, rail, and road access at Bella Coola. The district population is lower than others in the study area. Education levels and participation rates are comparable to other districts.

3.4.1.3 Regional District 47 - Skeena-Queen Charlotte

Within RD 47, Prince Rupert and Masset account for nearly 68 percent and 5 percent of the region's population and only 0.4 percent (combined) of the region's total land area. However, their size and/or location in the region (as well as existing infrastructure) may prove advantageous for exploration activities.

3.4.1.4 Regional District 49 - Kitimat-Stikine

The city of Kitimat, with a population of 11,533, is the most strategically placed city in the district. The district relies heavily on the forest industry and public sector, both of which are currently giving way to increased tertiary industry as well as tourism initiatives.

Table 3.6 Key Infrastructure and Major Employment Industries

Community	Key Infrastructure/Activities/Facilities	Major Industrial Employers (# employed)
Kitimat	21 greenfield industrial sites (11 on tidewater)	Alcan Smelters (1,800+)
	11,660 ha of developable industrial land	Eurocan Pulp & Paper Co. (630+)
	quarrying opportunities	Methanex (125+)
		Pacific Ammonia Inc
		Rivtow Marine and Barging
Masset	commercial fishing fleet	CB Island Fisheries
	2 Commercial fish processing plants	Omega Packing Company Ltd
		Graham Island Shake and Shingle Ltd
		Delmas Cooperative Association
		Greater Masset Development Corporation
		Northern Savings Credit Union
Port Hardy	fish processing	large commercial fishery (800-1,000 operators)
	wood manufacturing	aquaculture/shellfish operations
	tourism	seafood processing sector
	forestry/silviculture	100 sportfishing charters/outfitters
	varied tourism sector	nearby Provincial Parks
Prince Rupert	780 fishing vessels; 1300 fishermen	Skeena Cellulose Inc. (600+)
	11 processing plants (up to 2,200 employed)	Canadian Fishing Company (150+)
	1,500 salmon licenses	Northern Savings Credit Union (120+)
	largest fish cannery in the world (Allied Pacific Processors)	JS MacMillan Fisheries (100+)
		Ocean Fisheries (100+)
		Prince Rupert Grain (100+)
		Ridley Terminals (70+)
		North Coast Timber (50+)
		Canadian Stevedoring (50+)

Sources: Northwest Development Corridor and Port Hardy and District Chamber of Commerce

3.4.1.5 Education Levels and Labour Supply

Table 3.7 illustrates the percentage of the labour supply (1996 figures) in the principle centres of the study area, as a function of post-secondary diplomas and certificates, and university degrees. Provincial figures are approximately 30 and 14 percent, respectively.

Table 3.7 Labour Characteristics by District

District	Education Level (Post-Secondary Diploma/Certificate), %	Education Level (University Degree), %
43 - Mount Waddington	29.4	7.9
45 - Central Coast	28.5	8.5
47 - Skeena-Queen Charlotte	27	8.1
49 - Kitimat-Stikine	27	8

Source: BC Stats

3.4.2 Fisheries

The fisheries in the region can be divided into four categories:

- commercial;
- commercial-recreational;
- recreational; and
- aquaculture.

The commercial fishery in British Columbia remains a key source of employment and income for the province, and is the key resource sector for many small and medium size communities, and for more remote communities along the central and north coast areas.

Statistics from 1999 show that the salmon, herring, groundfish, wild shellfish, and other fisheries accounted for 210,000 tonnes and a landed value of over $300 Million. However, the 1999 wild salmon harvest was the lowest in 50 years, and has resulted in concerns over conservation. The decline in the salmon industry is being mitigated largely through aquaculture in B.C.

The commercial-recreational fishery in B.C. includes tourism operations of varying sizes, in populated and remote areas. Many of the communities in the study area specialize in this type of eco-tourism, offering the "whole package" to tourists by providing both the lodging and the "fishing" experience, while the industry is also expanding into incorporating other outdoor activities instead of recreational fishing. More detail is given in the Tourism section (Section 3.5.1).

Recreational sportfishing in tidal areas accounted for approximately $315 Million in the 1999 provincial economy, provided 3,400 seasonal jobs, and put to work over 800 charter operators (BC Fisheries).

Salmon farming in B.C.'s aquaculture industry reached 49,900 tonnes in 1999, an increase in nearly 7,000 tonnes from the previous year, and contributed $329 Million (88 percent of total aquaculture wholesale value) in wholesale value to the provincial economy (up nearly $65 Million from 1998). Nearly 80 percent of the salmon aquaculture industry is represented by Atlantic salmon (followed by Chinook at 18 percent and Coho at just over 3 percent). Aquaculture is an expanding sector in the study area, and in some cases, is attempting to offset losses in the traditional fisheries sector.

3.4.3 Challenges Facing Coastal Communities

Declining salmon catches since 1986 have affected the economies of coastal communities, and continue to present a threat to the economic base of communities who rely on the harvesting and processing sectors. The key communities identified above depend on the fisheries sector for employment, as seen in the example of Prince Rupert, which has nearly 800 fishing vessels and 1,300 fishermen (similarly, Port Hardy has between 800 and 1,000 operators in the commercial fishery). Within the processing sector, major industrial employers in these centres rely heavily on the salmon fishery (for example, there are eleven processing plants in Prince Rupert which, in total, employ nearly 2,200 people). These challenges are made worse by the lack of future prospects for the fisheries sector, and therefore the health of communities whose economy is reliant on fisheries and processing. There is no indication that the effects of depleted salmon stocks on the economy will be short-term in nature.

In the past five years, the Government of Canada has implemented measures to reduce the size of the oversized commercial fleet, as well as fund habitat restoration measures, rebuild salmon stocks, and increase resource and watershed stewardship. Furthermore, the government has funded programs to compensate vessel owners who were affected by certain strategy provisions, and to assist individuals who may have been displaced by these measures. The aim of these measures is to improve the long-term sustainability of the fisheries sector by improving habitat, which will in turn improve salmon stocks. Initiatives are still in place to increase stewardship, compensate for losses, diversify economies, and create an economic atmosphere to foster recovery of salmon stocks.

The forestry sector in the immediate area is also facing some challenges. Notably, one of the biggest issues is the economic health of Skeena Cellulose, in Prince Rupert. Skeena Cellulose was recently granted protection from creditors, with hopes of future ownership in the private sector. The sawmill in Prince Rupert, at full production, can employ over 1,300 employees, and 6,500 more are directly and indirectly employed as a result of the pulp and paper mills and log chipper and sawmill activities in other locations. The loss of Skeena Cellulose would greatly affect the economic base of the regional economy.

Competitiveness in the lumber industry is being hampered by high stumpage rates paid by northern mills and high transportation costs, as compared to other parts of Canada. There are presenting challenges to local industry which, in the key districts outlined above, economies rely heavily upon (household income dependency ranging from 22-45 percent).

3.5 Other Resource Use - Tourism, Sensitive Areas, Port and Shipping

This section addresses the state of the tourism industry in the identified areas, sensitive areas (including Marine Protected Areas), and the Land and Resource Management Planning (LRMP) processes, which are active to varying degrees in the study area. Transportation in key port cities is discussed at the end of the section, outlining infrastructure and facilities for road, rail, and sea access. The tourism industry and the status of land and resource (including marine resources) planning are major factors to consider in any discussion of oil and gas exploration.

3.5.1 Tourism

Many urban centres in the study area have growing tourism industries, or are in the process of establishing tourism operations, many of which are natural-resource based. For the centres of Kitimat, Masset, Port Hardy, and Prince Rupert, the following table elaborates on the existing tourism-amenity base and indicates the tourism strengths currently in the respective region.

How oil and gas exploration activities could affect the trend toward tourism and ecotourism in the area is unknown, as is the manner in which the industries could complement each other in community economic development.

Table 3.8 Tourism in Selected Centres

Municipality	Characteristics
Kitimat	sportfishing charters (20+)
	MK Bay Regional Marina
	Moon Bay Marina/Kitimat Village Marina
	Mount Layton Hotsprings Resort
	access to Kitlope Rainforest area
	18-Hole golf course
	Furlong Bay and Lakelse Lake Provincial Park
	ski trails
	Weewanmu and Bishop Bay hotsprings
Masset	sportfishing charters (9)
	freshwater and sea-fishing opportunity
	10 local hiking trails
	small craft harbour
	bird watching at Delkatla Wildlife Sanctuary
	ferry and seaplane tours
Port Hardy	sportfishing
	whale watching, sea kayaking
	scuba diving
	nearby Provincial Parks
	9-hole golf course
	nearby ski hill (Mt. Cain)
Prince Rupert	100 sportfishing charters/local outfitters
	whale watching, sea kayaking
	Pike Islands Marine Heritage Tour
	First Nations Archaeological Tours
	Centennial Golf Course
	ferry and seaplane tours

Sources: Northwest Development Corridor and Port Hardy and District Chamber of Commerce

Another aspect of tourism for coastal communities in the area is the Cruise Ship industry. Ports of call (e.g. Prince Rupert, Port Hardy, etc.) on the west coast directly and indirectly benefit from cruise ship activity[1]. There may be a potential for oil and gas industry activities and cruise ship activities to

1 A recent study reported that cruise ship activity in British Columbia resulted in a total regional impact of $282.3 million to the economy (CCG Consulting Group Ltd, 2000).

overlap. The requirements of these two industries may have to be addressed.

3.5.2 Sensitive Areas - Marine Protected Areas (MPAs)

Marine Protected Areas, a joint initiative between the Government of Canada and the Government of British Columbia (and part of the provincial Land Use Strategy), was proposed to be a comprehensive, inclusive strategy to identify sensitive areas along the Pacific coast of B.C., and to provide some level of protection for conservation and sustainability, and to address issues of resource conservation, pollution, habitat alteration, exotic species, and climate change. A discussion paper was released in 1998, but to date, the Strategy has yet to be developed. This is due, at least in part, to difficulties encountered when dealing with shared marine jurisdiction between the federal and provincial governments. The Strategy described in the 1998 discussion paper notes that minimum protection standards for marine protected areas would prohibit ocean dumping, dredging, and exploration for, and development of non-renewable resources.

There are currently ten designation types for marine protected areas in BC, at both the federal and provincial levels. In addition to the federal and provincial designations, there are municipal marine parks; however, they only offer protection for marine resources where Fisheries and Oceans Canada has established fishery closures within the boundaries of the park. There are only two instances in BC where this has occurred.

The provincial government has five designation types for MPAs: Ecological Reserves, Provincial Parks, Wildlife Management Areas, Designated Wildlife Reserves and “Protected Areas”. Agency participation and responsibility for these five types of MPAs currently rests with the British Columbia Ministry of Water, Land and Air Protection. Ecological Reserves are crown and private lands designated by the Lieutenant Governor in Council, under the *Ecological Reserve Act*. Ecological Reserves are areas suitable for research and education, representative of natural ecosystems in B.C., examples of modified environments that can be studied for their recovery or are habitats for rare, endangered or unique species. There are four marine Ecological Reserves within the north and central coast areas of B.C.

Provincial Parks are created through Order-in-Council under the *Park Act* or inclusion in a Schedule in the *Act.* The purpose of provincial parks is to set aside representative ecosystems, habitat and special landscapes and features with the broadest diversity of provincially significant biophysical resources. They also serve various recreation functions, including enhancing tourism opportunities and ensuring enjoyment by all residents of the province. There are three classes of provincial parks. Class A parks are dedicated to the preservation of natural environments for the inspiration, use and enjoyment of the public. There are fourteen Class A parks and two Class R parks (Recreation Areas) with marine associations in the north and central coasts of B.C.

Wildlife Management Areas (WMAs) are designated by the Ministry of Water, Land and Air Protection

(MWLAP). MWLAP can acquire and administer lands and designate them as WMAs, except if they are in an existing park or recreation area. Designation of land under a WMA does not affect any rights previously granted. The purpose of WMAs is to encourage appreciation of wildlife values while ensuring wildlife heritage is passed on to future generations by maintaining diversity and abundance of native species and their habitats, opportunities for the use and enjoyment of wildlife and harmony between people and wildlife. There are no marine Wildlife Management Areas on the north and central coasts of B.C.

Sections 15, 16, 17 and 101 of the *Land Act* allow the Province to reserve or transfer Crown land for various reasons in the public's interest. Designated wildlife reserves are mainly used as an interim measure before the ultimate establishment of a wildlife management area. There are 5 wildlife reserves on the north and central coasts of B.C.

The *Environmental Land Use Act* is used to designate areas with both examples of marine diversity, recreational and cultural heritage and special natural, cultural heritage and recreation features. It is used by a Land Use Committee of Cabinet to meet government's land use plan commitments and respond to concerns with the *Park Act*. The Kitlope Heritage Conservancy is the only marine "protected area" on the north and central coasts of B.C.

The federal government also has five designation types for MPAs: National Parks (Reserves), National Marine Parks (National Marine Conservation Areas), Migratory Bird Sanctuaries, National Wildlife Areas and Marine Protected Areas. Parks Canada is responsible for National Parks and National Marine Parks, Environment Canada is responsible for Migratory Bird Sanctuaries and National Wildlife Areas and Fisheries and Oceans Canada is responsible for Marine Protected Areas.

National Parks are created to protect natural environments that are representative of Canada's natural heritage. They are managed by Parks Canada to maintain their ecological integrity while providing opportunities for public understanding, appreciation and enjoyment. A national park is formally established with an amendment to the *National Parks Act*. Because coastal areas of B.C. are currently subject to treaty negotiations, final designation for Gwaii Haanas (and Pacific Rim on the west coast of Vancouver Island) National Park, therefore, it is referred to as a Park Reserve in the interim.

National Marine Conservation Areas (NMCAs) are established to protect and conserve a network of representative areas of the marine environments in Canada while providing education and enjoyment to the people of Canada and the world. The intent is to manage the parks to demonstrate how protection and conservation practices can be harmonized with the sustainable use of marine ecosystems. NMCAs are currently established under the *National Parks Act*; however, a proposed *Marine Conservation Areas Act* is currently before Parliament. An NMCA has been established at Gwaii Haanas and is currently the only NMCA on the north and central coasts of B.C.; however, Parks Canada's NMCA System Plan identifies five of the twenty-nine marine regions in Canada on the Pacific Coast: the Strait of Georgia, the Vancouver Island Shelf, Queen Charlotte Sound, Hecate Strait and the Queen Charlotte Shelf. Both Hecate Strait and the Queen Charlotte Shelf are represented in the Gwaii Haanas NMCA.

National Wildlife Areas (NWAs) are established under the *Canada Wildlife Act* on lands subject to federal jurisdiction and the administrative control of the Minister of Environment. They may be on land, internal waters or the territorial sea. The purpose of NWAs is to set aside nationally significant habitats for the protection of migratory birds and wildlife for the purpose of research, conservation and interpretation. There are currently no NWAs on the north and central coasts of B.C.

Migratory Bird Sanctuaries are established under the *Migratory Birds Convention Act*, which empowers Canada to enact and enforce regulations to protect those migratory birds listed in the Convention. There are no migratory bird sanctuaries on the north and central coasts of B.C.

Marine Protected Areas are designated, under the *Oceans Act*, by the Governor in Council, on the recommendation of the federal Minister of Fisheries and Oceans. Marine Protected Areas are established to conserve and protect:

- commercial and non-commercial fishery resources and their habitats;
- endangered or threatened marine species and their habitats;
- unique habitats;
- marine areas of high biodiversity or biological productivity; and
- any other marine resource or habitat as is necessary to fulfill the mandate of the Minister.

While no *Oceans Act* MPAs have been formally approved, four pilot MPAs were announced in B.C. in 1998: Gabriola Pass, Race Rocks, the Bowie Seamount and the Endeavour Hot Vents.

3.5.3 Land and Resource Management Plans (LRMP)

The study area includes three areas for which LRMP processes are planned, have been initiated, or are currently in progress. These are: the Central Coast Land and Resource Management Plan, the Queen Charlotte Islands - Haida Gwaii Land and Resource Management Plan, and the North Coast Land and Resource Management Plan. The LRMP process will guide the management of lands and activities which could affect the region’s ecosystems, amenities, and socio-economic environment. The Ministry of Sustainable Resource Management (MSRM) and the Land Use Coordination Office (LUCO, now the Resource Planning Division of the BC MSRM) work in conjunction with resource ministries to inform, develop, and implement LMRPs. LRMPs generally provide:

- broad land use zones defined on a map;
- objectives that guide management of natural resources in each zone;
- strategies for achieving the objectives; and,
- a socio-economic and environmental assessment that evaluates the plan. (BC MSRM, 2001)

The LRMP process is designed to be focused on ecosystem, social, cultural, and economic sustainability to determine current and future land-use. Decision-making is open and community based so that the needs of communities, the economy, and the environment inform resource management decisions. The recently initiated Central Coast Preliminary LRMP has instituted an ecosystem-based management system. Any activities related to oil and gas exploration with the potential to affect regions in the study area would necessarily have to take into account an existing LRMP or a planning process towards the establishment of a LRMP. Depending on the nature and precise location of exploration activities, one or more LRMP area may be directly involved. However, areas under the LRMP system would not include offshore or marine areas beyond the coastal zone.

The LRMP process is designed to identify sensitive and critical areas of importance to the ecosystem, local communities, and First Nations. The importance can be ecological, economic, or social in nature, and thus the LRMP process relies on stakeholder participation.

3.5.3.1 Central Coast LRMP

The Central Coast LRMP process is still underway. The provincial government has accepted the Central-Coast’s land-use table, which includes portions of the Great Bear Rainforest (96,458 hectares designated as the Spirit Bear protection area), pending consultation with 17 First Nations who are currently participating in the planning process. This area is environmentally and culturally significant in the region, and has implications for local economic development stakeholders in various sectors. Completion of The Central Coast LRMP will rely on agreement with the First Nations.

3.5.3.2 Queen Charlotte Islands - Haida Gwaii LRMP

The Queen Charlotte Islands-Haida Gwaii (QCI) LRMP process has been initiated, but to date there is no LRMP in place. Consultation with the community, the First Nations in the region, and other stakeholders is being carried out. The provincial government has released a background report entitled “An Overview of Natural, Cultural, and Socio-Economic Features, Land Uses and Resources Management”. The area includes 150 islands, 4,700 km of shoreline, and approximately 4,000 waterbodies of varying sizes. The area is home to over 240 species of birds, over 300 species of fish, 39 species and subspecies of plants and animals unique to the islands, and 116 exotic species.

Economically, the region is largely dependent on the tertiary/service sector (tourism and government - 68%), with 24% relying on the primary sector, mainly based on resource extraction such as logging and fishing. The Haida Nation is a strong voice in the community, and comprises a large portion of the population. There are two federally designated “Indian Reserves” in the region (Old Masset and Skidegate). The Haida Nation in conjunction with the Government of Canada cooperatively manage the Gwaii Haanas National Park Reserve, in the southern portion of Haida Gwaii. The site is a World Heritage Site which encompasses approximately 1,900 islands and islets.

It is expected that the QCI LRMP process will proceed in a manner much like the typical LRMP process, establishing overall objectives, economic objectives, environmental objectives, and social objectives, representing values and interests from a wide variety of stakeholders.

3.5.3.3 The North Coast LRMP

The North Coast LRMP process is not yet initiated. Mapping provided by the Province of B.C. shows that there are many marine and inland areas that fall within the LRMP region. It is fair to say that the direction taken by the underway Central Coast LRMP process and the upcoming QCI LRMP process would dictate direction taken in this region, and the types of sensitive and/or socio-culturally significant areas in the region would be similar to those found in adjacent LRMPs.

Where LRMPs are not yet in place, there may be other planning processes undertaken by the Ministry of Sustainable Resource Management that consider aquaculture, integrated resource use, or both.

3.5.4 Port and Shipping Activities

The port cities of Kitimat, Masset, Port Hardy and Prince Rupert are described in Table 3.7. The table briefly highlights transportation infrastructure from land and sea.

The Port of Prince Rupert is strategically located, with the largest installed infrastructure and port capacity. Statistics from Transport Canada note that the Prince Rupert port is frequently operating at excess capacity. Grain has constituted up to 35 percent of Prince Rupert's total export volume, and recently the port has been underutilized. Other centres selected within the study area offer shipping, storage and transportation infrastructure in various capacities, as seen in the table below.

Table 3.9 Rail, Road and Port Infrastructure, Selected Centres

Municipality	Rail	Road	Water
Kitimat	56 rail cars/day (avg), CN freight line extends across North America	Interprovincial Highway 37 via Highway 16 (links to Prince George and Edmonton)	container port facility (port handles 260+ vessels/year, exports over $1 Billion (1997))
	freight and passenger service (North-South)	Established freight industry; easily expandable rail cargo capacity	space for 11 tidewater terminals and manufacturing operations
Masset	-	TransCanada/Yellow-head Hwy (Graham Island Terminus of Hwy 16 to Skidegate)	BC Ferries services (Skidegate-Prince Rupert)
Port Hardy	CN Freight line for grain export	Highway 19 links to Victoria and other island centres	BC Island ferry service
			port development for deep sea ships and barges
Prince Rupert	CN Freight line	TransCanada Hwy (Hwy 16)	BC Ferries / Alaskan State Ferries service
	BC Rail north/south passenger/freight service	Established trucking industry infrastructure	6 terminal facilities (incl. 1 cruise terminal) - cargo, coal, grain, storage facilities.

Source: Northwest Development Corridor and Prince Rupert Port Authority

4.0 PHYSICAL ENVIRONMENT

In this section, the physical environment in the proposed exploration areas is reviewed and, where possible, compared with conditions in other areas where offshore hydrocarbon exploration and development activities are taking place. The focus of this section is on the physical environment as it relates to geohazard assessment, engineering design parameters, operational and safety concerns, and environmental impact assessment. The intent is to discuss the quantity and quality of available information from the perspective of defining conditions on a regional basis, given that any exploration activities will be preceded by detailed site work by the leaseholder. Detailed technologies and engineering implications are discussed in Section 5.

4.1 Physiography

The main areas of interest for future oil and gas exploration are the Queen Charlotte and Hecate Basins as outlined in Figure 4.1 (Terra Remote Sensing Inc. 1999). The high potential zones extend roughly from the north end of Vancouver Island through Queen Charlotte Sound and the western portion of Hecate Strait, including Dixon Entrance and the west coast of the Queen Charlotte Islands out to the Queen Charlotte Fault Zone.

The entire area is part of the Hecate Depression, a continuous, low-lying region extending from Puget Sound north to Alaska (Thomson 1981). The Hecate Depression is flanked by the Coast Mountains on the mainland side to the east, and by the open Pacific and the lower mountains of the Queen Charlotte Ranges to the west. The major physiographic features of this region are described in detail elsewhere (e.g. B.C. Ministry of Environment 1983, Petro-Canada Inc. 1983).

Coastal conditions are extremely varied, ranging from dynamic beaches with extensive sand flats to steep cliffs and deep fjords. The physical and biological characteristics of the shore zone throughout British Columbia are currently being mapped using a consistent approach based on a combination of oblique aerial video imagery and selected ground-truthing. The resulting data are then compiled into standard format databases, with an effective "data scale" of roughly 1:5000 (Howes *et al.* 1997). Although the aerial videography has been completed for the entire province, the associated databases are still under development. It is expected that the databases will be completed and become available to the public in the fall or winter of 2002 (Mark Zacharias, pers. comm.).

In a related effort, the Land Use Coordination Office (LUCO) is developing coastal resource and oil spill response atlases for the coast of British Columbia. The oil spill response atlases will incorporate information on biophysical characteristics of the shoreline, sensitivity to oiling and available technologies for oil spill response and cleanup. It is expected that these products will also be completed in the fall or winter of 2002. More information on coastal mapping initiatives is available through the LUCO website at http://www.luco.gov.bc.ca/coastal/mris/coasthm.htm.

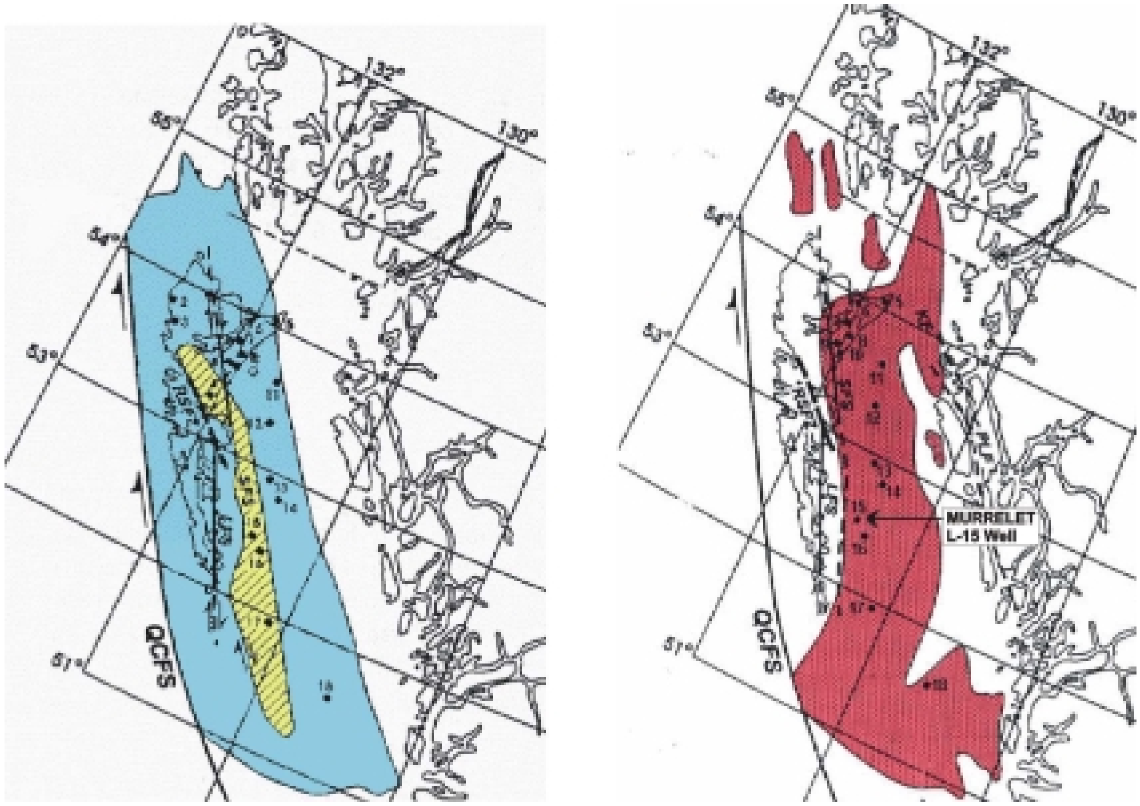


Figure 4.1 Oil and gas plays on the west coast. (Left: Cretaceous oil and gas play; yellow area is the more prospective region with moderate to high potential; Right: red area shows region of the Miocene oil and gas play. Pliocene play covers the northern portion of area north of the Murrelet L-15 well (from TRSI, 1999)).

4.1.1 Bathymetry

Queen Charlotte Sound, the southernmost waterbody under consideration in this review, includes the waters between the north end of Vancouver Island and Cape St. James at the southern tip of Moresby Island. Three major troughs, with water depths extending to 400 m, cut across the sound. Between the troughs lie the shallower waters of Cook Bank, Goose Bank and North Bank, with depths as shallow as 31 m over the eastern edge of Goose Bank (WCOEEAP 1986).

Hecate Strait lies to the north of Queen Charlotte Sound, between the mainland and the Queen Charlotte Islands. The strait narrows from about 120 km between the mainland and Cape St. James at the southern tip of the Queen Charlotte Islands, to roughly 55 km between Rose Spit and the mainland. Much of the western half of Hecate Strait consists of two shallow banks with water depths consistently less than 40 m: Dogfish Bank to the north and Laskeek Bank to the south. On the mainland side, a submarine valley deepens from 50 m in the north to 300 m in the south and continues southward and westward to the open ocean through the troughs on either side of North Bank in Queen Charlotte Sound (Figure 4.2).

Dixon Entrance is a broad east-west channel separating Graham Island from the islands of the southern Alaska Panhandle. Water depths decrease from 400 m where the channel meets the Pacific Ocean to 200 m at the mainland side. At its seaward end, Dixon Entrance is divided into two deep channels by a large shoal called Learmonth Bank that rises to within 35 m of the water surface. Dixon Entrance is largely separated from the waters of Hecate Strait to the south by Rose Spit, an extensive, dynamic feature protruding seaward more than 12 km to the northeast of Rose Point (Thomson 1981).

The western shore of the Queen Charlotte Islands is steep and rugged and drops sharply to water depths of more than 100 m. The continental shelf in this area is extremely narrow, extending offshore for less than 5 km off of Cape St. James to the south and up to 30 km in the north before the shelf break is reached at roughly 200 m water depth (Barrie and Conway 1996). The offshore areas of interest for oil and gas exploration extends beyond the shelf to water depths of about 2,100 m.

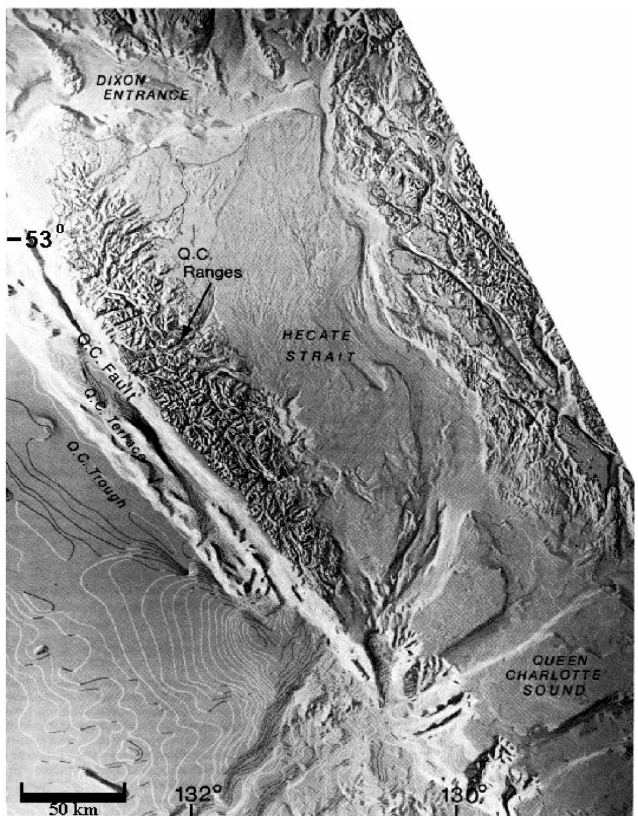


Figure 4.2 Oblique shaded-relief depiction of the topography and bathymetry of the Queen Charlotte area (from Sawyer 1989).

The regional bathymetry has a major impact on ocean currents and circulation patterns, water column mixing processes, wave conditions in coastal areas and areas of sediment deposition or erosion. An accurate knowledge of water depths and seabed slope angles is also required in order to select appropriate drilling units, to safely choose locations for any seabed installations and to identify operational hazards related to shipping activities.

Regional bathymetry of Dixon Entrance, Hecate Strait and Queen Charlotte Sound is covered by Canadian Hydrographic Service Charts 3802, 3902 and 3744, at scales of 1:200 000, 1:250 000 and 1:365 100, respectively. Larger scale, more detailed charts are available for many of the nearshore areas in this region, but these do not provide complete coverage of the main water bodies of concern to this project. Larger-scale field sheets used in the development of Charts 3802, 3902 and 3744 are also available through the Canadian Hydrographic Service (CHS).

All three charts are in fathoms and feet and are based on survey data collected prior to the 1970's and, in some areas, the 1940's. A metric version of chart 3802, numbered 3800, is currently under development. Additional data not incorporated into the existing charts, but collected over the period from 1973 through 1985, are available through CHS. These data consist of single beam echosounder readings at a 10 km line spacing. Data coverage on the west coast of the Queen Charlotte Islands is typically poor, given the dangerous conditions in the area and the low demand for charts of this region. In general, chart accuracy is approximately 1 percent of water depth (Terry Curran, pers. comm.).

Water depths in the proposed exploration areas are similar to those where offshore oil and gas production facilities are currently operating on both the Scotian Shelf and the Grand Banks of Newfoundland. However, both local slope angles and spatial variability in bottom topography are much higher than those encountered on the eastern shelves, even away from the coastline. Many relict beaches and drowned coastal features persist on the offshore banks and shoals, primarily as a consequence of the rapid, post-glacial sea level rise, the historically sheltered nature of the inland seas and the proximity to a tectonic margin (Vaughn Barrie, pers. comm.). These features require detailed hydrographic survey techniques, such as the swath bathymetry approach described in Section 5.1.3.2.

4.1.2 SEAMAP

The Seabed Resource Mapping Program (SEAMAP) is a national initiative to map Canada's offshore, coastal and aquatic lands. The initiative is supported by three federal government departments (Fisheries and Oceans, National Defence and Natural Resources) and is proposed as a partnership between industry, government and Canadian universities. The intent of the initiative is to provide data and products for users in the fishing industry, fisheries management, offshore oil and gas, offshore engineering, aquaculture, national defense, aquatic, coastal and ocean management, and scientific research; all within a national framework (http://seamap.bio.ns.ca).

SEAMAP is currently at the proposal stage, under consideration by the Federal Cabinet. While reviews to date have been excellent, it is not known at this stage if funding will be approved for this initiative. If approved, the program will likely start with demonstration projects in key areas of Canada, as identified on a national basis. Mapping of the Queen Charlotte Basin has already been established as a regional priority for the west coast (Richard Pickrill, pers. comm.).

The technical approach to seabed mapping will focus on the use of swath or multibeam bathymetry systems, accompanied by appropriate ground-truthing. While the technologies are currently available to proceed with such an initiative, the commitment of sufficient resources by the federal government is required in order to proceed (Richard Pickrill, pers. comm.).

4.2 Climate

The north coast of British Columbia has a temperate climate regulated by the prevailing onshore flow of marine air. On a large scale, regional climate and weather patterns are dominated by two atmospheric pressure systems: the North Pacific High and the Aleutian Low. The North Pacific High dominates in summer months, producing north to northwesterly winds along the outer coast. In winter months, the Aleutian Low becomes dominant, producing winds from the south to southeastern sectors. These prevailing wind patterns are modulated by coastal topography and are interrupted for days or weeks by eastward-migrating high and low pressure systems, which can produce intense storms (Thomson 1981).

Climatic conditions impact both operation and safety of offshore drilling activities. A discussion of climate can be separated into two parts: conditions during normal, or average, periods and those during extreme events. In general, extreme events govern the design parameters which impact the safety of offshore operations, while normal conditions are more important for operational considerations, structural fatigue issues and in assessing and controlling environmental impacts associated with offshore hydrocarbon exploration and development activities. Normal meteorological conditions will be addressed in this section, with storm events described in Section 4.4.

The day-to-day meteorological factors affecting offshore drilling operations include winds, temperature, visibility and ceiling, wind chill and freezing spray (Petro-Canada 1983). An extensive system of land-based climatological stations is operated by the Atmospheric Environment Service (AES) of Environment Canada throughout the coastal areas of British Columbia. Parameters reported from these stations include radiation, humidity, pressure, visibility and cloud cover, temperature, precipitation and wind. Over 30 years of measurements are available for many coastal stations in British Columbia (AGRA 1998).

Petro-Canada (1983) performed extensive analyses of the historic records from land-based climatological stations surrounding Dixon Entrance and Hecate Strait. Based on the existing database at that time, Petro-Canada concluded:

> "Temperature extremes, wind chill and freezing spray are unlikely to pose serious problems to drilling operations off the Queen Charlotte Islands. Occasionally visibility and ceiling height would be low enough to restrict aircraft operations. Visibility is poorest in the summer and fall when advection fog occurs, and low ceilings are common in winter. The simultaneous occurrence of low visibility and low ceiling is rare."

Although many of the land-based climatological stations examined by Petro-Canada have since been decommissioned (Gary Myers, pers. comm.), the remaining stations, such as Sandspit, Langara and Cape St. James, will now have almost 20 years of additional measurements. Up-to-date information on available climate data can be obtained through the Climate Station Database maintained by AES (http://www.msc-smc.ec.gc.ca/climate/station_catalogue/index_e.cfm).

While it would certainly be worthwhile to update the analyses of historic climate data to include the more recent measurements, it is not expected that the above conclusions would change in any significant manner. The impacts of climate change are discussed in Section 4.5 of this report.

4.2.1 El Niño and La Niña

El Niño is a disturbance in the natural cycle of the ocean and atmosphere in which a warming occurs in the tropical sea surface waters of the eastern and central Pacific Ocean. This warming adds considerable amounts of heat and moisture to the earth's atmospheric circulation at the tropics resulting in large-scale changes to the earth's atmospheric circulation particularly at the tropics and to a lesser extent elsewhere around the globe. This occurs every two to seven years. La Niña is the cooler phase counterpart to the ENSO and weather conditions are in general opposite to those occurring during El Niño.

Impacts on British Columbia from El Niño include milder air temperatures, warmer coastal waters, rises in sea level, and a reduction in snowfall. The effects on total precipitation (rain and snow) vary considerably across British Columbia. While short-term changes in weather patterns are associated with the ENSO, it is not expected that this phenomenon would have a significant impact on the design and safety of offshore facilities.

4.3 Water Level and Ocean Currents

Variations in water levels are caused by several factors--of these, tides are by far the most significant in the northern coastal waters. Tides within the area of interest are mixed, predominantly semi-diurnal, meaning that there are two complete tidal exchanges per day. However, the mixed nature of the tides leads to significant inequalities in both the magnitude and the duration of successive exchanges.

In coastal waters, tides interact with bathymetry in a number of ways, leading to significant spatial variations in tidal range and timing of high and low water stands. In the waters surrounding the Queen Charlotte Islands, the mean tidal range varies from 3.0 m at the entrance to Queen Charlotte Sound to 4.8 m midway along Hecate Strait, and from about 3.5 m at the mouth of Dixon Entrance to 5.0 m at Prince Rupert. On a large tide, ranges can exceed 7 m at several coastal locations (Thomson 1981).

In addition to tides, significant variations in water level can result from factors such as storm surge; large scale, periodic, climatic cycles such as El Niño/La Niña; and the local effects of river runoff. Variations in water level are continuously measured at several permanent stations around the north coast (reference ports); shorter records have been obtained from the many secondary ports on both the Queen Charlotte Islands and the mainland coast. In general, knowledge of water level variations in the region is good (Bill Crawford, pers. comm.). Details on the locations of the primary and secondary ports can be obtained from the Canadian Hydrographic Service.

Tidal variations in water level are the primary driving force for ocean currents throughout the coastal waters of British Columbia. However, winds and freshwater inputs are also important contributors to the ocean current regime. As for the general climate in the region (Section 4.2), the ocean climatology can be roughly divided into summer and winter seasons based on the predominant wind direction. All three driving forces (tides, winds and freshwater inflows) interact with the local bathymetry to form complex circulation patterns throughout the region.

Knowledge of ocean currents is required for both engineering and environmental aspects of offshore exploration and development. The magnitude of currents impacting either fixed or floating structures plays a role in assessing structural loads, anchoring requirements, and expected scour depths. Current strength may also impact the timing of sensitive operations such as reconnecting to a wellhead. From an environmental perspective, the ocean currents in the area of an oil spill are perhaps the single most important factor determining the ultimate fate of spilled oil in the environment.

While it is a common requirement that exploratory drilling be preceded by site-specific current measurements by the operator, a broader-based knowledge of current conditions is still required in order to place the site-specific measurements into the context of regional and longer-term processes. The WCOEEAP (1986) recommended that:

> "...the Department of Fisheries and Oceans develop and implement a program to improve general knowledge of current movements in the region, and, in particular, in the area of a drilling location when one is proposed."

As a result of this recommendation, Fisheries and Oceans Canada implemented a major ocean research program in northern waters. Between 1989 and 1995, DFO undertook an extensive measurement program, including moored current meters, tide gauges, ocean drifters and measurements of water properties. This work has been funded by the Panel for Energy Research and Development (PERD) and DFO, with the primary goal of establishing a basic understanding of surface flows in the event of an oil spill. The focus of the field work was on summer conditions, based on the Panel's recommendation to limit drilling activities to summer months. A summary of the research program and the associated publications can be viewed at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/qci/qci.htm.

Figure 4.3 shows the locations of current meter moorings in northern waters for the period from 1982 through 1995. Records varied in length between two and eight months.

In addition to the field measurement program, a series of numerical models have been applied to these waters (Hannah *et al*. 1991; Foreman *et al*. 1993; Ballantyne *et al*. 1996; Cummins and Oey 1997). These models vary in the numerical approach, grid formulation and resolution, and in the specific processes included in each model.

In summary, the existing database provides a reasonable picture of surface flows during summer months based on the ocean drifter data, and a good picture of regional, sub-surface flows from the moored current meters. Information on surface flows in winter months is limited, and measurements on the west coast of the Queen Charlotte Islands are insufficient to characterize flow patterns in that region. Long-term measurements, including the significant effects of the ENSO, are also not available at this time (Bill Crawford, pers. comm.).

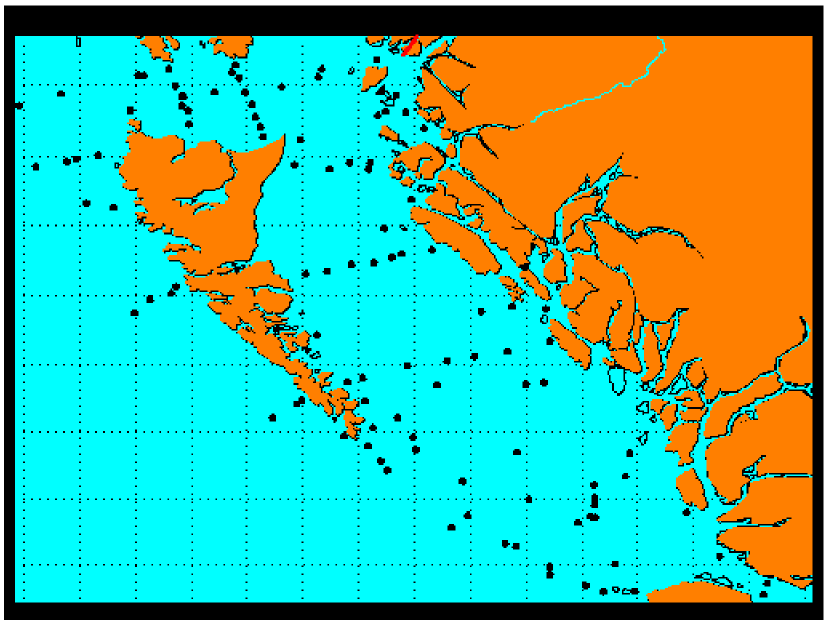


Figure 4.3 Current meter mooring sites for the period 1982 through 1995 (courtesy of W. Crawford, Fisheries and Oceans Canada).

With respect to understanding the regional processes, the various numerical models give a reasonable picture of tidal currents in northern waters, with the exception of Dixon Entrance, where internal tidal currents are significantly under-predicted (Crawford *et al*. 1998). Finer-resolution models may improve this predictive ability. Predictions of maximum tidal current speeds from an updated version of the Foreman et al. (1993) model are shown in Figure 4.4.

Since 1995, work has continued on defining the regional circulation patterns, and has focused on features such as the region around Cape St. James. The flow in this region is dynamic and complex, with current speeds reaching 2.5 ms^{-1}. Flow close to the cape is so turbulent that surface waters cool as they pass by, through the effects of mixing with deeper water (Crawford *et al*. 1995). A persistent plume of cold water is evident well to the west of Cape St. James on satellite images (e.g.

http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/qci/qci.htm), indicating the importance of the Cape to regional circulation patterns. Evidence also exists for a re-circulation of water in the region to the east of the Cape (Crawford *et al.* 1995).

In comparison with other regions of Canada, where offshore hydrocarbon exploration and development activities are currently underway, the ocean currents and circulation patterns in the northern waters of British Columbia are complex and highly variable. Associated with this complexity is a high degree of uncertainty, particularly with respect to predicting the fate of contaminants discharged to the marine environment. This complexity and variability is a consequence of several factors, but is strongly related to the combination of complex bathymetry (Figure 4.2) and large tidal exchanges.

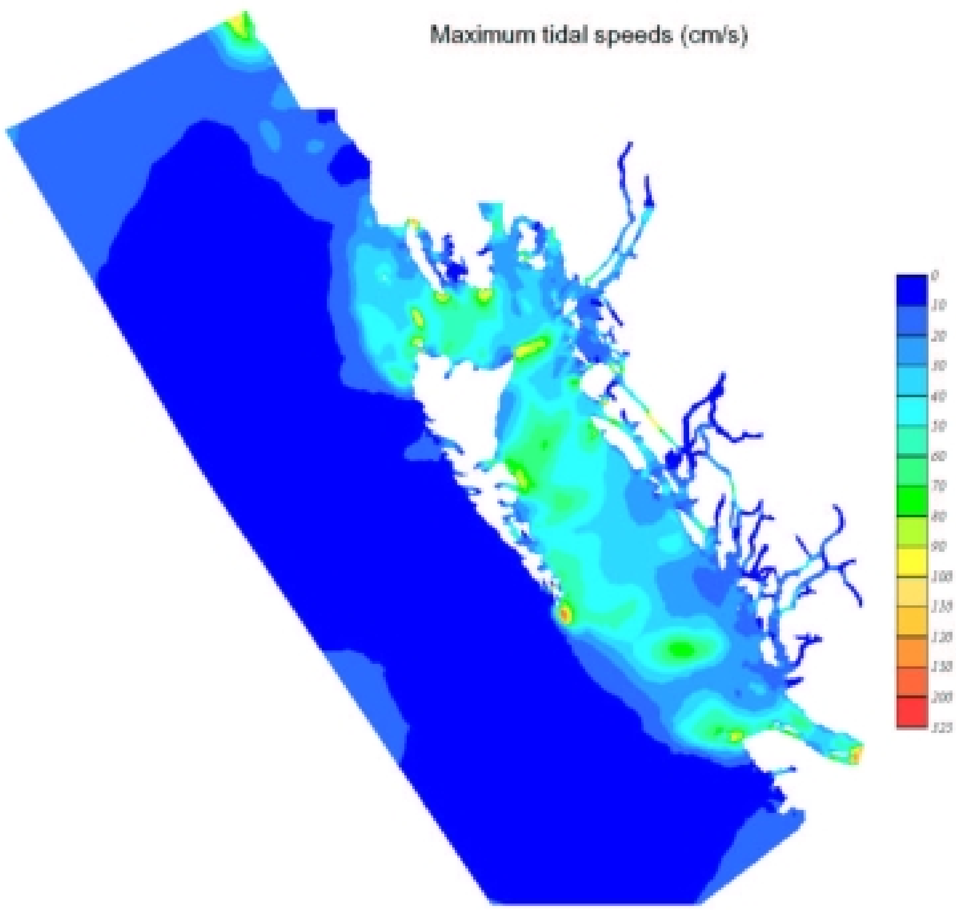


Figure 4.4 Maximum tidal current speeds in northern British Columbia water (courtesy of M. Foreman, Fisheries and Oceans Canada).

4.4 Storm Events

The normal climatic conditions described in Section 4.2 are routinely disrupted by storm events associated with eastward-migrating low pressure centres. These depressions follow two major tracks: one group originates in the northwest Pacific and moves northeastward along the Aleutian Islands, reaching the Alaska coast as fully-developed cyclones; while the second group originates in mid-ocean and reaches the coast of British Columbia at the height of storm development, causing severe winter gales.

The storm activity off the British Columbia coast is distinctly seasonal, with most summer storms following the northern track to the Alaska coast. In October, storm frequency and intensity increase rapidly with more storms following the southerly track. Throughout the winter months, storms regularly reach the coast at two- to three-day intervals. There is a gradual decrease in storm activity through April and May as the storm pattern, frequency and intensity return to summer conditions (Petro-Canada 1983).

Strong winds, high seas and strong currents are produced by storm events. These factors typically determine the maximum environmental loads on marine structures and thus the safety of various structural elements, but also limit the conditions under which various drilling-related operations can proceed. Knowledge of the wind, wave and current conditions at a proposed drilling site is required to choose safe equipment for that site and to select the most effective equipment to maximize the efficiency of drilling operations.

Table 4.1 Design Parameters For Typical Drilling Units (Petro-Canada 1983)

Drilling Unit	Operating Limits	Survival Limits
Drillship		
wind speed (kmh^{-1})	90	185
current speed (cms^{-1})	80	100
wave height (m)	10	30
wave period (s)	<10	>10
Semisubmersible		
wind speed (kmh^{-1})	110	185
current speed (cms^{-1})	100	100
wave height (m)	15	30
wave period (s)	<14	>14

Note: To restrict drilling activities, operating limits for wind, current and sea state must be exceeded concurrently.

Table 4.1 shows the design parameters and operating limits of a typical drillship and semi-submersible, circa 1980 (from Petro Canada 1983). These limits should be considered only as a general guide, since available equipment is continuously evolving with both development of new types of drilling units together with refined designs for existing platform types (see Section 5.2). Bottom-founded drilling units such as jack-up platforms and gravity-based structures (e.g. Hibernia) do not have the same limitations.

From an environmental perspective, storm-driven currents may be the most significant factor impacting the fate and dispersal of contaminants discharged to the marine environment, while sea state parameters will influence the design and effectiveness of oil spill contingency plans and equipment.

In addition to defining the wind, wave and current conditions to be expected during a storm event, the speed during which storms can cause operating conditions to deteriorate is a significant aspect of determining routine environmental safety (WCOEEAP 1986). In its report, the Environmental Assessment Panel concluded that six hours notice of impending storms is the minimum time required to temporarily cease operations, make the drillstring secure and safely disconnect from the wellhead. The Panel recommended that approval for exploratory drilling not be given until the Atmospheric Environment Service of Environment Canada is satisfied that the capability exists to provide a minimum of six hours advance warning of severe storms.

While storms are of significant concern, the predictable storm events off the British Columbia coast are of lower intensity than those faced by offshore structures in other areas of the world (see Section 4.4.1).

4.4.1 Winds

The waters surrounding the Queen Charlotte Islands are commonly reported as the windiest in Canada, with severe winds more common than in other areas (WCOEEAP 1986). The strongest wind ever recorded for Cape St. James is 177 kmh^{-1}, recorded during a storm in January 1951. At that time, winds were recorded only every six hours; the lighthouse keeper estimated that winds had reached a steady 200 kmh^{-1} with gusts to 225 kmh^{-1} during the peak of the storm (Petro-Canada 1983).

Extreme wind speeds are typically estimated from long-term data records in the area of interest. In addition to the land-based climatological stations discussed in Section 4.2, the Atmospheric Environment Service and DFO together maintain a set of marine weather buoys in northern waters. The marine weather buoys were installed between 1987 and 1993, providing roughly 10 years of historical data for wind-over-water conditions. Station locations are shown in Figure 4.5, and parameters measured at each type of station are given in Table 4.2. The MAREP station shown on Figure 4.5 reports the same data as the climatological stations, identified as marine weather reporting stations on Figure 4.5. However, the MAREP station also reports weather information on VHS radio.

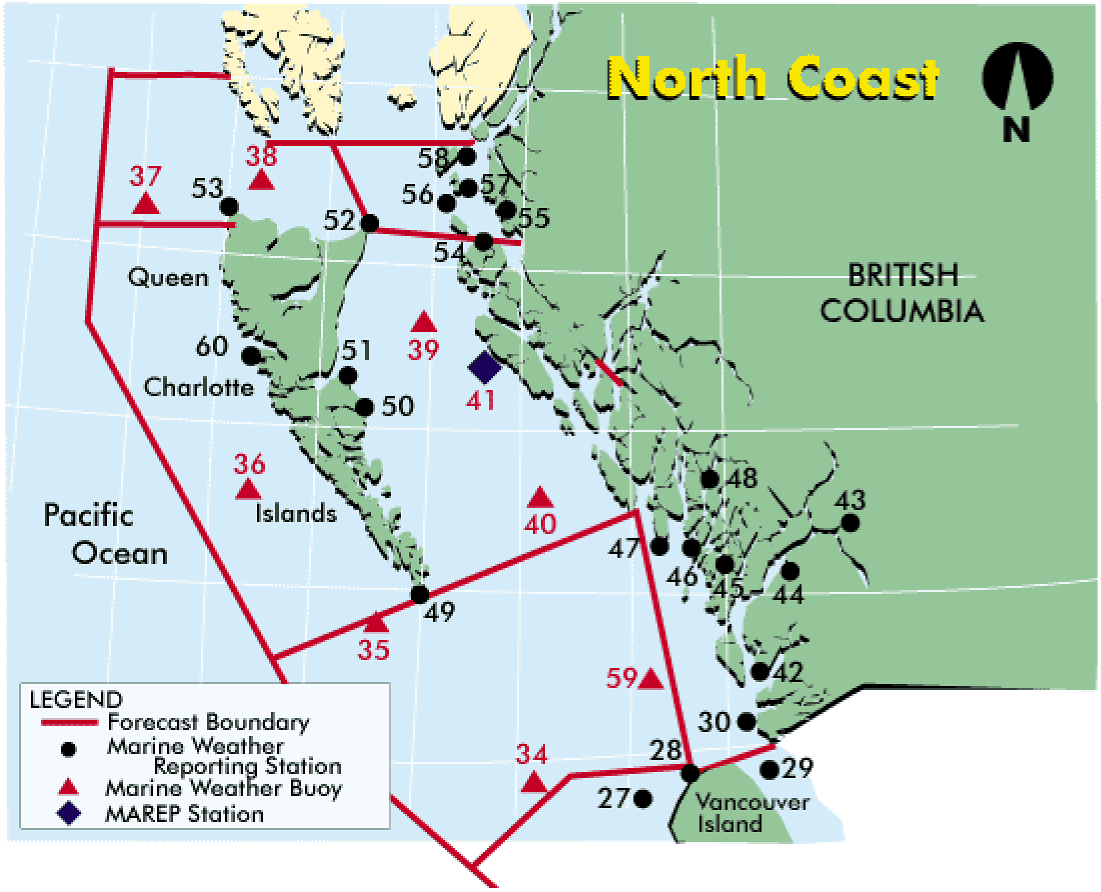


Figure 4.5 **Locations of land-based marine weather reporting stations (including MAREP station) and marine weather buoys in northern British Columbia waters.**

Table 4.2 **Parameters Reported at Marine Weather Observation Stations (after AGRA 1998)**

Met-Ocean Parameter	**Station Type**	
	Marine Weather Reporting Station	**Marine Weather Buoy**
Air Temperature	T	T
Pressure	T	T
Wind Speed and Direction	T	T
Wave Height		T
Wave Period		T
Sea Temperature		T
Limited readings from some stations:	T	
Visibility	T	
Sky Cover/Precipitation	T	

Although the wind speeds in northern British Columbia waters are high, similar conditions are also experienced in other areas of the world where offshore hydrocarbon exploration and development activities are currently active. In the Gulf of Mexico, tropical cyclones reaching hurricane speed (exceeding 120 kmh^{-1}) are the largest factor leading to weather-related shut-downs; most companies include 5 to 7 days of weather-related production losses each year in their business plans (Epps 1997).

Extreme winds over Canadian waters have been estimated as part of the wave hindcasting projects described in the next section (Canadian Climate Centre 1992). A brief comparison of the regional distributions of 50- and 100-year return period wind speeds for each coast shows that extreme wind speeds are roughly 10% higher for the eastern continental shelves, with six-hour values reaching 119 kmh^{-1} in areas where hydrocarbon production activities are already in progress. In comparison, the offshore facilities in the Gulf of Mexico are regularly exposed to wind speeds that exceed the maximum values estimated for both the east and west coasts of Canada.

4.4.2 Surface Waves

Given the close relationship between storm winds and surface waves, wave conditions in the northern British Columbia waters can also be considered relatively severe. Extreme wave conditions are typically estimated from a combination of historic record analyses and numerical modelling of previous extreme storm events (hindcasting).

In addition to the buoy locations shown on Figure 4.5, AES and DFO maintain weather buoys offshore from the coast of British Columbia. Of the total of 17 buoys, eight are shown in Figure 4.5, three are located in the Strait of Georgia, two off of the west coast of Vancouver Island, and three offshore buoys are located about 400 km to the west of the British Columbia coast. All buoys were installed between 1987 and 1993; in general, the period of record is longer for the offshore buoys than for the coastal network. Short-term, historical data are also available for a number of primarily nearshore sites (e.g. Prince Rupert, Kincolith, Kitimat, Port Simpson).

Marine observations of wind conditions and sea state are also available from platforms of opportunity, including both ships and fixed platforms such as drilling rigs. Although this database can be extensive in areas close to major shipping lanes, this type of observation is considered to be significantly less reliable than those obtained from the weather buoys.

Wave hindcasting is relied on world-wide to estimate extreme wave conditions for engineering design purposes (e.g. the 100-year return period wave) in areas where the measurement database is insufficient for this purpose (most offshore areas). In wave hindcasting, sea state conditions are estimated for historic extreme storm events using a combination of numerical modelling and other analysis techniques. Extreme storm events are typically identified using a variety of criteria, and, in the absence of direct wind measurements, wind fields are developed from atmospheric charts for each storm event. These wind fields are then used to estimate site-specific wave conditions in the area of interest for each storm event. The resulting long-term simulated database is then used to estimate extreme wave parameters. Available wind and wave measurements are used to calibrate and verify the numerical modelling and analysis procedures.

A wave hindcasting study for the British Columbia coast was completed in 1992 for the Atmospheric Environment Service (Canadian Climate Centre 1992). This study was part of a multi-part project to estimate extreme wind and wave conditions for Canadian offshore waters. Project results indicated that extreme wave conditions are similar for the west coast of Canada and for the eastern continental shelves, with 100-year return period significant wave heights on the order of 13 m for both the Grand Banks of Newfoundland and the exposed areas of the west coast. It should be noted that the methodology used in these studies predicts deep-water wave conditions only; the effects of shallow water and strong currents on wave heights were not considered.

Since the early 1990’s when the extreme wave studies were completed for Canadian waters, the impacts of several extreme storm events on both coasts of North America have prompted the re-assessment of wind and wave hindcast procedures. This re-assessment has focused on the accuracy of the wind fields used to predict wave conditions. The development of wind fields from atmospheric pressure charts uses a combined quantitative and qualitative approach, and thus relies on the expertise of the hindcaster.

In recent years, wind prediction methods have been improved and new wind fields developed for historic storm events (e.g. NCEP-NCAR Renalysis Project (NRA)). These wind fields have recently been used to produce a 40-year wind and wave hindcast for the North Atlantic (http://www.oceanweather.com/aes40). High quality wave measurements allowed evaluation of the accuracy of the wind fields. Although the NRA wind fields were found to produce wave hindcasts of good quality, wind fields still required reanalysis and enhancement using analyst-interactive techniques (Swail and Cox 2000).

For the B.C. coast, the 1992 estimates of wind and wave extremes could be updated based on the improved wind and wave climate databases, and also considering advancements in techniques for predicting wind fields in addition to inclusion of the effects of shallow water and strong currents. Given the large grid size of the NRA wind fields (2°), it is not clear if they will be appropriate for predicting wave conditions in coastal B.C. waters.

4.4.3 Wind-Driven Currents

In addition to creating surface waves, storm winds have several impacts on ocean currents and circulation patterns. In open ocean conditions, winds will create surface currents flowing in the downwind direction at a few percent of the wind speed. In shallower waters, interactions between the wind forcing and the bathymetry can lead to considerably more complex circulation patterns. In nearshore waters where freshwater inputs can lead to density stratification of the water column, the response to wind forcing is yet more complicated.

Several modelling efforts have contributed to our understanding of ocean currents and circulation patterns in the waters surrounding the Queen Charlotte Islands. In addition to the studies mentioned in

Section 4.2, Crawford et al. (1999) have modelled the response of these waters to wind forcing. For this exercise, the local winds measured at the AES buoys (Section 4.4.1) were used to drive the model, and comparisons were made with the summer drifter studies. Limited data were available to verify model predictions for the more extreme winter storms.

4.4.4 West Coast Marine Weather Forecasting

The state of marine forecasting for the west coast of British Columbia, particularly the north coast, has significantly improved since the mid-1980's. Specific improvements were sought at that time in the areas of storm event forecasting and advance warning time. The occurrence of a "marine bomb" event, or rapidly developing low pressure system, in October 1984 in which several fishing vessels were lost was a contributing factor to this need for improvement, as was the direct observation of wave conditions reaching or exceeding the 100-year return period event during several other storms.

The Environment Canada weather office and forecast operations for the Pacific and Yukon regions are based in Vancouver. The west coast marine weather forecast areas presently served are illustrated in Figure 4.6 *(http://www.weatheroffice. ec.gc/NatMarine/BC/index.html). A dedicated marine forecast desk, for both nearshore (coastal and 50-100 km out) and offshore marine areas, has been in operation since 1985 and considerable experience has been accumulated since that time. The forecasting unit operates on a 24 hour, seven days a week basis, and issues wind and sea state forecasts every six hours which cover the subsequent 24 hours with an outlook for the following 24 hours.*

Marine forecasts consist of two parts: a descriptive synopsis of the prevailing weather patterns, plus a detailed weather forecast. A sample for Hecate Strait is listed below.

> **Synopsis:**
> A ridge of high pressure along the coast will move inland tonight.
> A rapidly deepening low will track northwards to lie about 250 miles west of the Charlottes tonight. The associated front will sweep over the Charlottes Monday afternoon and reach the lower mainland Tuesday morning. A trough of low pressure will follow across the Charlottes Monday night.
> Over northern waters winds will rise to gale force southeast tonight. A brief period of storm force winds is expected Monday morning in advance of the front. Winds will ease to strong southerly with the passage of the front. Southerly gales ahead of the trough will shift to strong to gale force westerlies in its wake.
> Over southern waters winds will back into the southeast and rise to strong to gale as the front nears Monday.

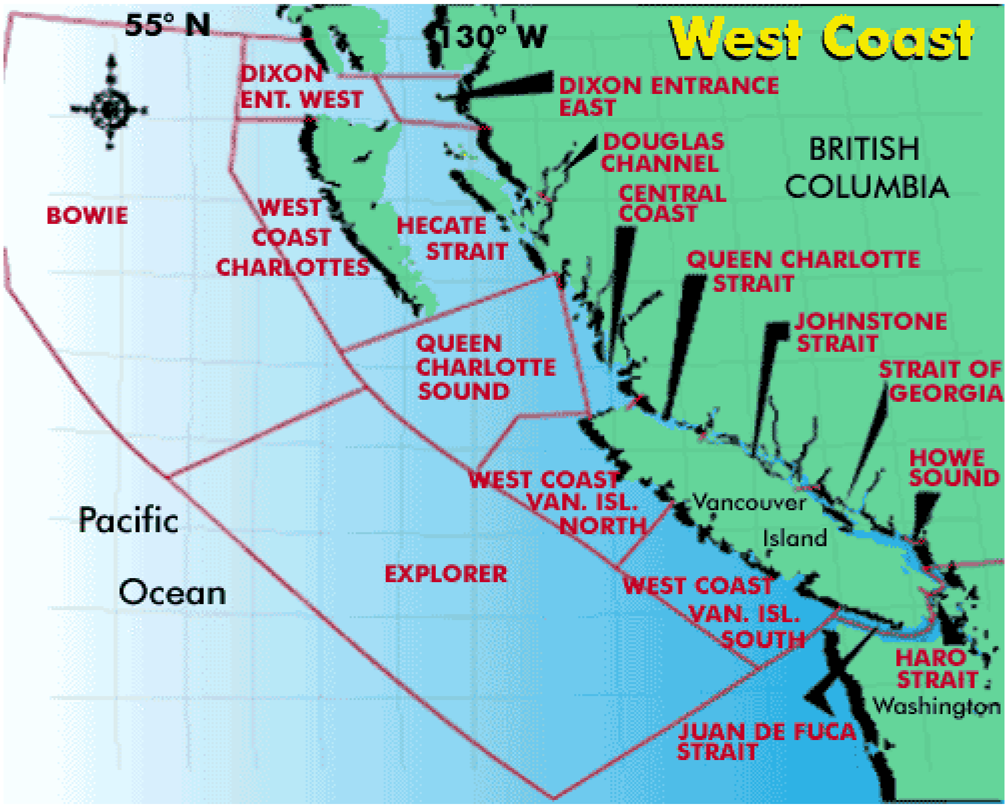


Figure 4.6 Weather forecast areas for British Columbia marine waters.

Forecast:
<u>Storm warning continued.</u>
Winds northeasterly 5 to 15 knots veering to southeast 20 this evening and rising gales 35 overnight. Winds rising to southeast gales 40 to storm force 50 Monday morning then easing to southerly 25 late Monday afternoon. Cloudy. Rain Monday. Seas near one metre building to 2 to 3 metres tonight and to 4 to 6 metres Monday morning. Outlook. Strong to gale force southerlies veering to strong westerly.

In addition to the regularly-scheduled marine forecasts, special marine weather warnings or weather advisories are issued as required:

STORM WARNING

STORM WARNING ISSUED FOR THE COASTAL WATERS OF BRITISH COLUMBIA BY THE PACIFIC WEATHER CENTRE OF ENVIRONMENT CANADA AT 8:49 PM PDT SUNDAY 14 OCTOBER 2001.

STORM WARNING ISSUED FOR BOWIE.

A 977 MILLIBAR LOW WILL MOVE ACROSS THE WESTERN SECTIONS OF THE BOWIE REGION ON MONDAY. WESTERLY STORM FORCE WINDS OF 50 TO 55 KNOTS ARE EXPECTED TO DEVELOP LATE MONDAY AFTERNOON AND EVENING AFTER LOW HAS PASSED.

FURTHER DETAILS FOLLOW IN THE NEXT REGULAR MARINE FORECAST AT 9:30 PM PDT.

The marine forecast desk is primarily served by a network of marine weather reporting stations and buoys (Figure 4.5)*. The stations report their parameters* (Table 4.2) *via satellite on an one hour basis, with observations being distributed to the AES observation network for application in numerical forecasts and as guidance information for the marine forecast desk.*

Marine observations (e.g., wind and sea state) are also reported to the observation network by ships of opportunity traveling through the region. These observations are rarely continuous for more than a few days and the geographic areas that they cover along the coast are somewhat random. Wind and wave observations from ships of opportunity are less accurate than buoy measurements, and are used in a qualitative manner by the forecast desk. However, ships of opportunity do report accurate measurements of atmospheric pressure; these pressure readings serve an important role as early-warning indicators for “marine bomb” events. Observations from ships of opportunity are reported every 6 hours.

Wind forecasts are prepared by Canadian Meteorological Centre (CMC) in Montreal using a numerical wind-prediction model *driven by the network of observations and surface analysis charts. Surface winds are supplied to* a *numerical wave forecasting computer model at CMC which is run twice a day and provides forecasts up to 48 hours. The* wave-forecasting *model uses a coarse grid with resolution on the order of 80 to 100 km.* This grid spacing has been found to be too coarse to fully resolve wave conditions during intense storm events.

The CMC forecast information is used as guidance by the marine forecast desk to produce their own subjective forecasts. Typically, the marine forecaster will modify the CMC forecasts based upon the specific marine regions, the latest observations, and their wave forecasting experience. Thus, the forecasting procedure represents a combination of data-driven numerical modelling coupled with interpretation and adjustment by experienced meteorologists.

In the early 1990's the forecast unit followed a “marine bomb” checklist to minimize the chance of these weather systems developing unnoticed. However, shortly after, the official *checklist was eliminated: the sophistication of the numerical forecast models and the increased experience of the forecasters made this task unnecessary. Weather system information is now well managed and rarely does a storm go undetected.*

Weather forecasts are currently verified through comparison with observed winds at two stations in the West Coast Vancouver Island North forecast area (Figure 4.6): Sartine Island and Solander Island. A statistically-rigorous procedure is used to assess forecast accuracy, with results reported for each month of the year. *The marine forecast unit indicates that it can adequately predict gale force and stronger events with a six hour or better notice time. Existing wave forecasts are believed to be accurate to within 0.5 to 1.0 m.*

Additional forecasting tools at the disposal of the marine forecasting desk include the Forecast Production Assistant, also known as the Pacific Wave Forecasting System (PWF). *The* PWF *includes an embedded wave model and allows the forecaster to adjust surface pressures as input to the model to allow better wind forecasts and more accurate hindcasts for specific forecast areas of interest. Generally, this is a tool that would be applied* in hindcast mode *for specific customers (e.g. offshore operators, or ships with specific vessel routing requirements) and is not used for* routine weather forecasts.

The marine forecast unit maintains good cooperative working relationships with the United States Weather Centre offices in Juneau, Alaska which results in shared information and mutual benefit to the forecast user communities along the British Columbia coast.

4.5 Gas Hydrates

Gas hydrates are solid forms of the commonly occurring gases in offshore sediments. Marine gas hydrates form in locations where the temperature and pressure regimes are sufficient to maintain the solid phase; on the western Canadian continental margin, hydrates are found below a water depth of approximately 800 m (David Mosher, pers. comm.). Gas hydrates are relatively abundant in offshore areas, having been retrieved by bottom draggers on numerous occasions.

Hydrates are typically identified on seismic profiles as bottom-simulating reflectors (BSRs). BSRs are evident on about half of the mid-continental slope; extensive research was conducted on one hydrate deposit through Leg 146 of the Ocean Drilling Program (Hyndman et al. 2001).

Gas hydrates pose some hazards to exploratory drilling operations. The drilling itself may cause dissociation of the solid phase, increasing the free gas content in the bottom sediments and potentially leading to decreases in sediment strength and slope stability. However, gas hydrates are a common occurrence in other waters where hydrocarbon exploration and development activities are ongoing, and there exists considerable experience in dealing with the potential hazards. In addition to posing a potential hazard to drilling activities, hydrates are seen as an undeveloped resource to be exploited in the future as the appropriate technologies are developed.

4.6 Faulting and Earthquakes

The area around the Queen Charlotte Islands, Dixon Entrance, Hecate Strait and Queen Charlotte Sound is known to be one of the most seismically active areas of the world. However, as discussed later in

Section 5, many existing offshore oil and gas developments have been designed for similar seismic activity.

Among the most important seismo-tectonic features in this area is the northwest trending Queen Charlotte Fault (QCF) that forms the transform boundary between the North American Plate to the east and the Pacific Plate to the west (Figure 4.7). The QCF lies within 10 to 20 km (6 to 12 miles) off the west coast of the Queen Charlottes Island and transects the northern portion of the Petro-Canada lease area. Several large earthquakes have been ascribed to the movements along the QCF with a 1949 earthquake of Magnitude 8.1 (M8.1) and a few other events exceeding M7. The 1949 M8.1 event was triggered by a fault break several hundred kilometres long and resulted in a fault displacement of about 8 m (26 feet). The most recent one of these events was the M7.4 earthquake that occurred in 1974 near the southern tip of the Queen Charlottes Islands. Another M8.2 event occurred on the northward extension of the QCF along a segment known as the Fairweather Fault in Yakutat Bay, Alaska in 1899.

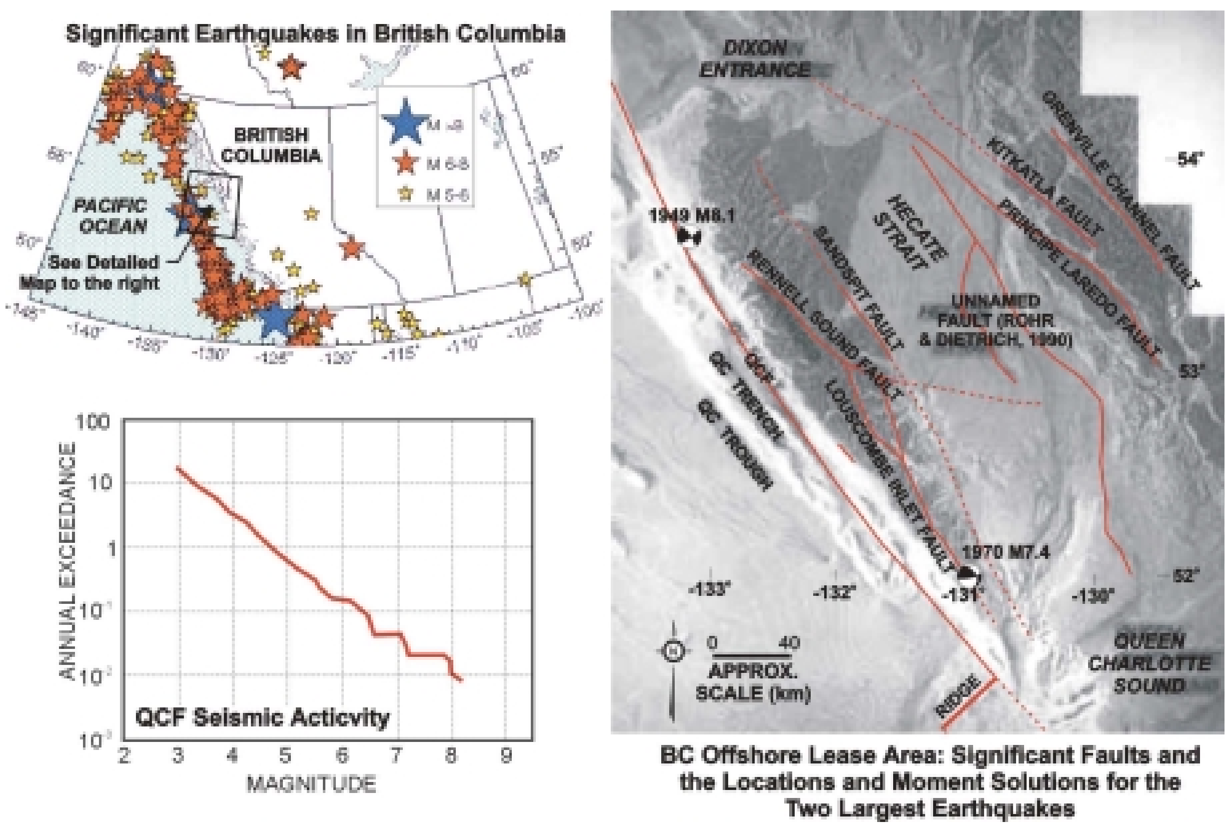


Figure 4.7 Seismicity and Faulting around the Queen Charlotte Islands

The Yakutat Bay earthquake was triggered by a several hundred kilometres long fault break and resulted in a displacement of 15 m (49 feet). Such an earthquake is expected to occur within 3 to 15 km (2 to 9 miles) below seafloor. Several other shallow, northwest trending faults cross the Queen Charlottes Islands. Some of these faults have been identified from the seismic data obtained during the earlier offshore oil and gas Exploration and Production (E&P) activities in this area and the geophysical survey of the Geological Survey of Canada (Rohr and Dietrich 1990; 1991). From west to east, most notable ones are the Rennel Sound Fault and the Sandspit Fault. The Rennel Sound Fault follows the centre of Moresby Island. The Sandspit Fault begins from the northeastern portion of Moresby Island south of Sandspit and appears to continue to north central Graham Island. It has been hypothesized that the cluster of seismic activity in the north central Graham Island is ascribable to the Sandspit Fault, although it is possible that these activities are due to deeper faults that are yet to be identified. Another fault has been proposed in east central Hecate Strait based on seismic data (Rohr and Dietrich 1990), the northern portion which also appears to be seismically (earthquake) active. The historical earthquake data and the length of fault trace indicate that seismicity along the QCF is capable of generating an earthquake between M8.5 and M9.0 (see, e.g., Slemmons and McKinney 1977). M7 earthquakes are likely to occur within 3 to 15 km (2 to 9 miles) below seafloor along other active faults west of QCF.

When assessing the potential impact of faults and fault movements on the location and design of offshore oil and gas facilities, it is necessary to estimate the relative age of fault or time since the last apparent movements or displacements along the fault. For designing structures it is considered appropriate to assess the likelihood of movements since the last ice age, i.e., within the past 12,000 years. Faults that could have moved since then are deemed potentially active. As discussed in later sections, investigations would be undertaken to identify and avoid the locations of potentially active faults for locating offshore oil and gas facilities.

4.6.1 Accelerations and Ground Motion

The results of probabilistic seismic hazard analysis presented by CGS (1992) indicates that the 1 in 475 year earthquake peak horizontal acceleration (PHA) west of central Hecate Strait and north central Graham Island is between 0.32 and 0.4 times the acceleration due to gravity (g). The corresponding peak ground velocity (PGV) is between 0.32 and 0.4 m/s (12.6 to 15.7 foot per second). Further east, the PHA for 1 in 475 year earthquake decreases to 0.12g along the eastern shoreline of Hecate Strait and the corresponding PGV is 0.24 m/s (9.4 foot per second).

The historical seismicity in this area was re-examined in connection with the recent proposal of changing the seismic design basis in the Canadian National Building Code from 1 in 475 earthquake to 1 in 2,500 year (Adams, Halchuk and Weichart 2000). These results indicate that in the onshore areas of the Queen Charlotte Island and its immediate offshore vicinity, a 1 in 2,500 year event would lead to a PGA between 0.8g and 1.2g. In north central Hecate Strait the corresponding PGA is between 0.4g and 0.6g, while in the remainder of the lease areas are likely to experience a PGA between 0.16g to 0.40g.

The commonly used code of practice for designing fixed offshore platforms, API RP 2A, has in-built earthquake design procedures that account for the level of ground motion in US offshore areas. These procedures can be readily modified to account for the anticipated ground motions in British Columbia offshore.

4.6.2 Tsunamis

Tsunamis or sea waves are generated by sudden vertical motion of the seafloor resulting from an earthquake or a submarine landslide. The seismo-tectonic regime in the vicinity of Dixon Entrance, Hecate Strait and Queen Charlotte Sound is dominated by strike-slip mechanism and is thus not perceived as particularly tsunamigenic. However, the seismic activities are likely to cause landslides, which in turn may trigger tsunamis. Tsunamis generated by distant subduction earthquakes may also affect this area. Tsunami waves travel at velocities of several hundred kilometres per hour and affect areas several thousand kilometres away. The tsunamis from the Aleutian Islands are therefore likely to reach the areas off the Queen Charlotte Islands within minutes after the trigger. These events are therefore also of concern in the design of offshore oil and gas facilities around the Queen Charlotte Islands. Areas most vulnerable are adjacent to steep onshore bluffs, submarine slopes, and enclosed basins. Several tsunamis have been reported in the coastal areas of British Columbia and Alaska Panhandle. Most significant among these was the tsunami generated during a 1958 earthquake on the Fairweather Fault. A large landslide triggered during this event crashed into Lituya Bay generating 30 m (100 feet) waves that stripped trees to 520 m (1700 feet) elevation on the opposite shoreline. A non earthquake-related submarine landslide destroyed a part of Skagway Harbour in Alaska in November 1994.

Satake (2001) reports an analytical study of tsunami in the Pacific Rim triggered by a large landslide in the Hawaiian Islands and estimated that the tsunami height could be 30 m (100 feet) in the western margins of Dixon Entrance and Queen Charlotte Sound. Lynett *et al.* (2001) also proposed a numerical model for tsunamis. The site-specific tsunami-related design parameters including wave heights and run-up can be estimated for the oil and gas developments in British Columbia offshore lease areas following such procedures. These parameters should then be used in structural design and risk management of offshore oil and gas facilities.

4.7 Fault Movement, Slope Stability and Liquefaction Potential

Among the significant geotechnical issues for the design of offshore oil and gas facilities are fault movement, submarine slope stability and liquefaction potential. For managing these risks, the areas of potential instability are first identified from shallow geophysical, bathymetric and oceanographic surveys so that the facilities can be located in lower risk areas. It is difficult to estimate ground movements for fault break, slope instability and liquefaction using rigorous analytical procedures. Worldwide experience and empirical methods are usually relied on for estimating the effects of these instabilities. For instance, a conservative (upper bound) magnitude of fault movement can be estimated using empirical relationships based on observations (e.g., Wells and Coppersmith 1994). The ground movements due to potential slope instability and liquefaction are similarly estimated for a trigger (e.g., an earthquake) with a large return period (typically 1,000 year) using soil strengths from geotechnical testing and following empirical procedures such as Hynes-Griffin and Franklin (1984), and Youd and Idriss (1996). Where appropriate, more sophisticated finite element computer models can be used to predict soil movements and the impact on facilities. The offshore oil and gas facilities should be designed for these low-likelihood ground movements.

Shallow faults and the extent of deformation of unlithified seafloor sediments are often identifiable from careful interpretation of high resolution seismic survey data. In certain conditions, the deformation of the sediments overlying shallow faults is inferred to be due to fault movements or creep and the underlying fault is deemed as potentially active. Bathymetric surveys can look for topographic patterns associated with slope instability. Such signatures of slope instability include toe-bulge, hummocky seafloor and talus heaps near the foot of steep submarine slopes. The presence of gas in seafloor sediments can often be identified from the high resolution seismic survey because gassy sediments absorb a significant portion of the seismic energy and wipes out the reflections from underlying layers. In some areas of British Columbia offshore gassy sediments are known to be associated with slope instability.

After completion of a detailed geophysical survey, areas of potential soil instability can be further investigated using geotechnical in-situ testing tools and sampling procedures. These investigations typically involve piezocone penetration testing (CPT), pressuremeter testing (PMT) and drilling and soil sampling. Laboratory tests are carried out on recovered samples to estimate soil strength and other engineering properties. The objective of the geotechnical investigation is to estimate the shear strength of the soil, based on which the possible soil stability can be assessed. These issues are discussed in more detail in Section 5.

4.8 Summary

In summary, the northern waters of British Columbia present a complex physical environment, with highly variable bathymetry, strong winds and currents, and high waves during storm events. The region is also one of high seismic activity, with the associated risk of slope failure and tsunami generation. Conversely, the significant risk to offshore facilities posed by icebergs on the Grand Banks of Newfoundland is not found on the west coast of Canada.

The extent of our knowledge of the physical characteristics of the west coast marine environment varies, depending on the physical aspect under consideration, and is highly dependent on the extent of previous regional data collection efforts. In general, our current state of knowledge regarding the physical environment of these waters has improved significantly since the 1986 report of the WCOEEAP.

Although the physical characteristics of the northern waters are relatively complex and there are areas where our knowledge base needs improvement, the technologies to do so are readily available and need only the dedication of sufficient resources to the task. In other jurisdictions such as the east coast of Canada, the collection of the required data has proceeded through the combined efforts of government and industry as offshore activities proceeded from the planning through the implementation stages.

The physical conditions under which offshore hydrocarbon exploration, development and production activities occur impact engineering designs, operational procedures and environmental impacts associated with any contaminant releases to the marine environment. Uncertainties in the physical parameters discussed in this section can be dealt with through standard approaches such as increased factors of safety included in engineering designs and operational procedures, while environmental concerns can be reduced through the incorporation of additional spill prevention measures into offshore equipment. The net effect of high uncertainties in the physical conditions under which offshore activities are to occur is to increase the cost of offshore activities and reduce the economic feasibility of a given project, rather than to limit the technical feasibility of offshore exploration.

5.0 ENGINEERING

The objective of this section is to review the significant engineering issues that impact the economics and safety of exploration and development activities for the offshore oil and gas industry. The focus of the following sub-sections is on recent technological advances and operational procedures, particularly those relevant to British Columbia offshore areas. Advances in the areas of safety and risk management have been outlined. The performance of existing offshore structures under severe seismic and climatic conditions is also reviewed to qualitatively assess the reliability of the current state-of-practice in the offshore oil and gas industry.

There are five sequential phases in a typical offshore oil and gas development:

- seismic and geophysical surveys;
- exploration;
- development;
- production; and
- decommissioning.

Important engineering and technological aspects of each of these phases, as well as the performance and risk associated with these activities, are discussed in the following sections.

5.1 Seismic and Geophysical Surveys

The initial geophysical surveys are undertaken to provide a three-dimensional (3-D) image of subsurface geological structures. The seismic surveys are primarily used to identify the "areas of closure," which sometimes act as hydrocarbon traps. The feasibility of exploratory holes depends on the size of these hydrocarbon traps. Seismic surveys must be properly planned and designed in relation to the geology of the study area. They are seldom effective in the first attempt and several surveys may be needed for achieving the necessary definition and confidence. The initial seismic surveys are also used to estimate the fluid pressure in the formations and to identify the presence of gas, although it is not possible to distinguish gaseous hydrocarbons from other naturally occurring gases such as carbon dioxide or nitrogen. Enhanced accuracy of seismic surveys and innovative use of these data have increased the success ratio of offshore oil and gas exploration drilling and reduced the cost of these operations and their environmental impact.

Seismic surveys involve measurements of travel times of reflected or refracted seismic waves. The interpretation of seismic data requires assumptions regarding the transmission characteristics of the geologic units. Therefore interpretation of seismic data requires judgement and experience. Until drill holes are completed to confirm the subsurface conditions the inference from seismic surveys only provide indications of probable conditions.

Further geophysical surveys are undertaken before, during and after exploratory drilling. These surveys include gravity and geomagentic surveys, shallow seismic surveys and other seabed mapping surveys for detailed geological hazard assessment. Additional geophysical measurements are carried out during exploratory drilling (Measurement While Drilling or MWD) to assess the formation pressures and porosity.

The developments in information technology and communication have resulted in utilization of broad-band seismic data, and a significant reduction in turn-around time between generation and analysis of geophysical data, leading to virtually real-time project management for an exploratory drilling program. This, in turn, has greatly reduced the risks of borehole instability and blowout and consequent occupational hazard and environmental impacts.

5.1.1 Seismic Survey

A conventional 2-D seismic survey involves towing the arrays of source and receivers from a survey vessel in a single row. An acoustic wave is generated from the source and the arrival of the wave reflected or refracted from the boundaries between different geologic units is recorded. Air Guns are often used to generate acoustic waves and hydrophones to record the reflected or refracted waves. A typical surveying program would include several such recordings along parallel survey lines spaced 0.5 to 1 km (0.3 to 0.6 mile) apart, usually in two orthogonal directions. The appropriate orientation of these lines requires a good understanding of the geologic structure within the study area. These surveys are undertaken under favourable weather conditions so that the quality of sound recording is acceptable.

From the interpretation of 2-D seismic survey data, the subsurface structure of a vertical slice is deduced and the slices from individual survey lines are treated as stand-alone results. Subsequent interpretation involves identification of geological relationship between neighbouring vertical slices to develop a 3-D subsurface map. The quality of a 2-D seismic interpretation depends on the experience and insight of the geophysicist into the acoustic characteristics of the geologic material being surveyed.

Since 1975, 3-D recording and interpretation techniques have become available involving simultaneous recording of reflected acoustic waves by a set of parallel arrays of hydrophones. A 3-D survey provides a significantly greater amount of information for survey grids (instead of survey lines of a 2-D survey) that may be spaced as closely as 100 m (330 feet) apart. Improved computer capabilities allows for the rapid analyses and interpretation of the vast amount of information generated in a 3-D seismic survey. This advance has resulted in more reliable and detailed subsurface imaging and an improved prediction of drilling results. Initially 3-D survey was utilized solely for oil or gas field development optimization but in the past ten years has become a valuable exploration tool to identify smaller exploration targets.

The latest development is the 4-D or time-lapse measurement, where recording devices are buried in the seafloor over an oil field. This technique is mainly utilized in reservoir management and to assist in the judicious drilling of late field life development wells to maximize recovery.

Air Guns primarily generate compression waves (p-wave) by blowing a compressed air pulse into seawater. The array of source and recorders are towed by the survey vessel in a single row in a 2 dimensional (2-D) survey, or in multiple rows in a 3-D survey. A portion of the seismic energy generated by the air guns gets converted into shear waves (s-waves) at the water-soil interface. Since water cannot transmit shear wave, the reflection pattern of s-waves cannot be measured with a receiver array towed above seafloor. The subsurface information contained in the s-waves is, therefore, lost in a conventional seismic survey. Use of multi-element geophones placed at the seafloor for recording the s-waves has also begun in recent years to utilize the information (Huffman and Castagna, 2001).

5.1.2 Supplementary Geophysical Information

Supplementary geophysical data are obtained from gravity and geomagnetic surveys. The gravity and magnetic surveys allow identification of “anomalies” or variations from regional averages and subsequently improve the 3-D picture of a sedimentary basin. These are relatively inexpensive compared to seismic surveys and the measurements are sometimes utilized in converting seismic travel times to depths. Modern high-resolution aero-margnetic surveys are flown from specially equipped aircraft at 60 to 90 m (200 to 300 feet) altitude and can provide details such as fault trace and near surface volcanic rock.

Additional data are collected during drilling (*i.e.,* Measurement While Drilling or MWD), which include vertical seismic profiling, magnetic resonant imaging (MRI), gravity and resistivity measurements. The first MWD tools went in service in 1978. Neutron Porosity Measurement capability was added to these tools in 1987, geo-steering and pressure detection capabilities in 1993 and MRI in 1997. These tools can now operate over broader pressure and temperature ranges and in various chemical environments. For instance, resistivity devices are available for use in water- oil- and synthetic- based drilling muds. MWD is also extensively used for controlling hole trajectory and steering in multilateral and horizontal directional drilling.

5.1.3 Seabed Mapping Technologies

The geophysical survey techniques described above are used primarily to map deep subsurface structures with the intent of identifying hydrocarbon reservoir rocks and the associated trapping structures. Additional information is needed on sea floor and shallow subsurface geology, seabed geotechnical properties and morphology for the following objectives:

- to optimize the design of the subsurface seismic survey program and to aid in interpretation of survey results;
- to assess regional and site-specific geohazards;
- to optimize the selection of drilling rigs and placement of drill holes;
- to define design parameters for sea floor installations;
- to assess the environmental impacts of exploration and subsequent phases of offshore oil and gas activities (development, production and decommissioning).

In this section, the technologies currently used to map and interpret the features and characteristics of the sea floor and shallow subsurface are summarized. These techniques include swath or multibeam bathymetry, sidescan sonar, acoustic seabed classification, high resolution seismic reflection profiling, visual observations, seabed sampling, laboratory testing and in situ measurements of geotechnical parameters.

5.1.3.1 Navigation and Positioning

An integral part of any seabed mapping or sampling procedure is accurate positioning. Historically, LORAN C was the most commonly used navigational method for regional surveys in Western Canadian waters. The accuracy of the LORAN C system varies with location, depending on position relative to the fixed base stations. In the Queen Charlotte and Hecate Basins, positional error based on LORAN C can be up to one nautical mile (Vaughn Barrie, pers. comm.).

In recent years, access to the satellite-based Global Positioning System (GPS) has become essentially universal. The Global Positioning System was originally designed for the U.S. military and is funded and controlled by the U.S. Department of Defense (DOD). The system consists of a set of 24 or more satellites that each orbit the earth once every 12 hours. Signals from at least four individual satellites are required in order to calculate position in three dimensions together with an accurate time signal. Signal access is available to civilian users world-wide with the use of a GPS receiver (Dana 2000).

Prior to May 2000, signal accuracy for non-military users was intentionally degraded by the DOD through the implementation of selective availability, a time-varying bias in the satellite signals. However, post-processing of the data using differential methods relative to fixed base stations allowed higher levels of accuracy to be achieved. In the early 1990's, the Canadian Coast Guard installed a network of differential base stations at British Columbia lighthouses. In the United States, the Federal

Aviation Agency has established the Wide Area Augmentation System (WAAS), blanketing North America with a differential signal available to most new "high-end" GPS receivers (http://gps.faa.gov/Programs/WAAS/waas.htm).

Since May 2000, selective availability has been turned off, allowing general access to the non-degraded signal. Current levels of accuracy for GPS are on the order of 100 m in horizontal position for basic readings from the GPS satellite system, with accuracy on the order of several metres using the differential system. Differential carrier-phase tracking with Real Time Kinematic (RTK) processing, although not yet in common use, achieves centimetre-level accuracy in both horizontal and vertical position for a moving remote receiver (Dana 2000; GeoAcoustics Ltd. 2000).

As a result of the accuracy of the currently-available navigation and positioning systems, subsea data can be accurately located, improving our ability to locate facilities away from hazardous areas and assisting in engineering evaluations to design for hazards.

5.1.3.2 Swath Bathymetry

Perhaps the most significant recent advancement in seabed mapping technologies has been the widespread adoption of swath bathymetry techniques for both precise water depth measurement and mapping of sea floor morphological features. A swath bathymetry system uses high frequency acoustic pulses generated by hull-mounted transducers to measure travel time between the ship and the sea floor. While a single beam echosounder obtains a single depth measurement under the survey vessel for each acoustic "ping", swath systems obtain many measurements across a transect perpendicular to the ship's path.

Many different types of systems and methods are available for swath bathymetric measurements. These include multibeam systems consisting of an array of individual narrow-beam transducers, mechanical or electronic scanning of a single beam, electronic beamforming systems and phase comparison techniques. Although many different types of systems are available, all essentially measure discrete reflections from small patches of sea floor. The term multibeam bathymetry is often used interchangeably with swath bathymetry to describe the general technique, rather than to identify a particular type of system.

The widespread application of swath bathymetric survey techniques has been facilitated by the combination of accurate navigation through GPS, high-speed digital data acquisition systems and advancements in both transducer technology and digital data processing techniques. With achievable swath widths on the order of five to ten times water depth, high-resolution bathymetric maps with complete coverage of the sea floor can be readily developed. Although survey resolution and accuracy are functions of water depth, ship speed and system configuration, typical values would be on the order of a few metres horizontal resolution and centimetres in vertical accuracy in shallower waters (David Mosher, pers. comm.). An example of a bathymetric map generated from a multibeam system is shown in Figure 5.1.

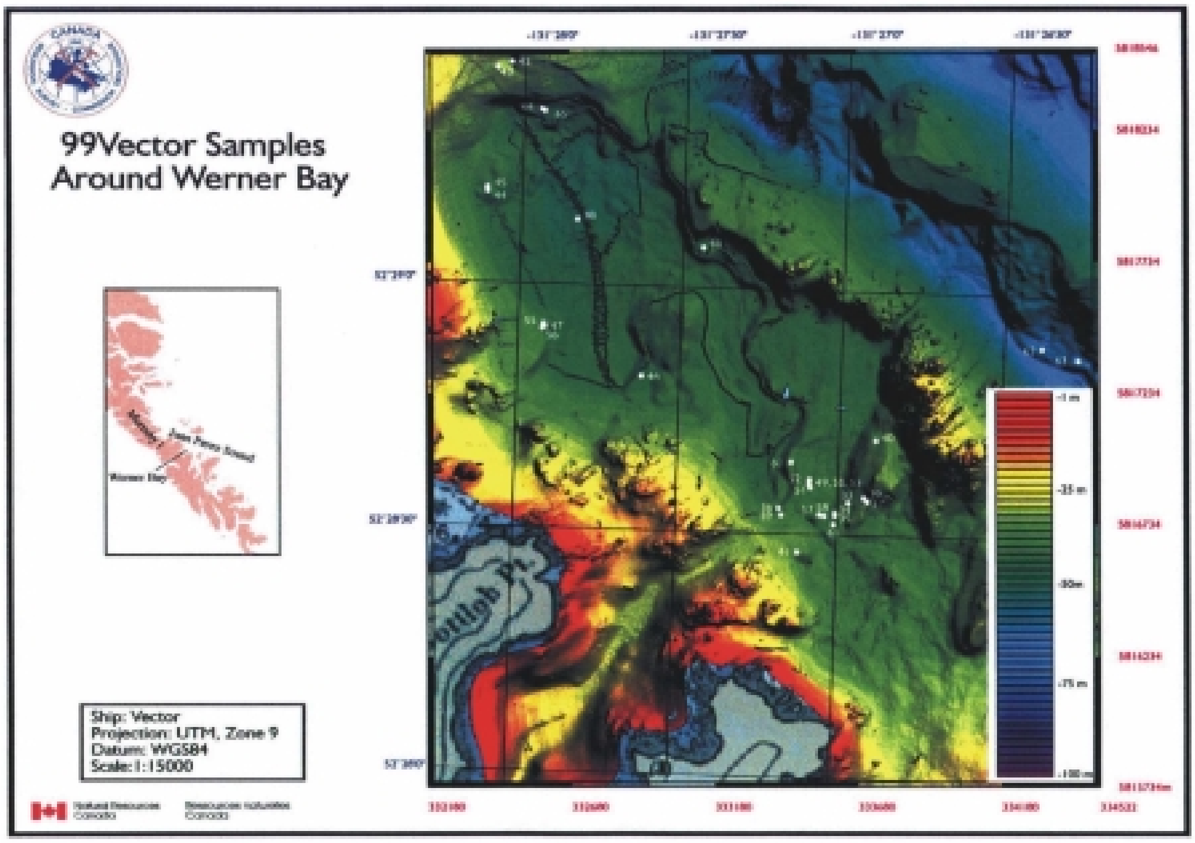


Figure 5.1 Colour-banded bathymetric map developed from multibeam data collected near Werner Bay, Queen Charlotte Islands (from Josenhans and Harding 1999)

In addition to accurate mapping of bathymetry, swath systems have provided valuable information for the mapping and interpretation of surficial morphological features, and for the accurate assessment of submarine slope stability. Figure 5.2 shows an example of multibeam data collected off Mapleguard Spit, on the east coast of Vancouver Island. In the top image, bathymetric data have been presented in a sun-illuminated format, highlighting bottom morphology. The middle image shows slope angle in a plan-view format, while the bottom image shows the depth profile along a selected cross-shore transect. Backscatter data, although not shown in Figure 5.2, can also be used to aid in interpretation of seabed texture and surficial morphology.

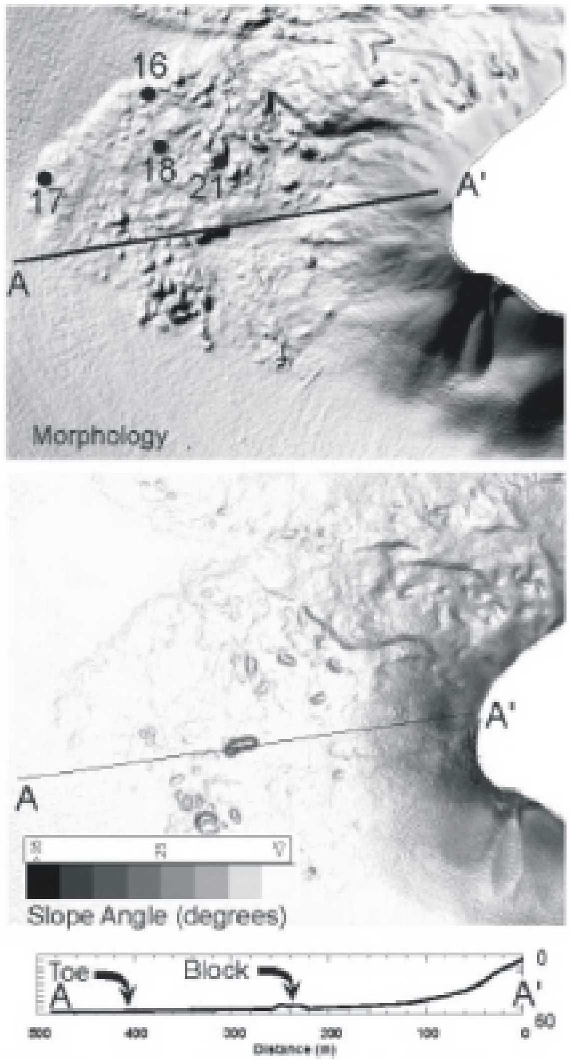


Figure 5.2 Morphology (top) and slope angle (middle) images and depth profile (bottom) of the southern failure lobe at Mapleguard Spit on Vancouver Island. The profile is at a 1:1 scale (from Mosher et al. 2001).

5.1.3.3 Sidescan Sonar

Sidescan sonar systems have long been the traditional method for imaging the sea floor for purposes of surficial morphological assessment. A sidescan sonar uses a wide-angle beam to measure the acoustic reflectivity of the sea floor, providing information on surficial texture in addition to morphology. Sidescan systems are typically towed in a "fish" close to the seabed in order to enhance the measurement of sea floor reflectivity. As a consequence of this operational configuration and the available data processing methods, sidescan systems do not give accurate bathymetric information. However, horizontal resolution is much higher than for a multibeam system, allowing better resolution of seabed morphology (Philip Hill, pers. comm.).

Although the basic technology behind these systems has remained unchanged in recent years, improvements in transducers and system electronics have led to significant increases in signal quality. In addition, digital systems and sophisticated post-processing software packages are now available, greatly improving the ease with which scale-corrected mosaics of the sea floor can be developed. Figure 5.3 shows a sidescan sonar mosaic of the area near Grief Point, on the east coast of the Strait of Georgia.

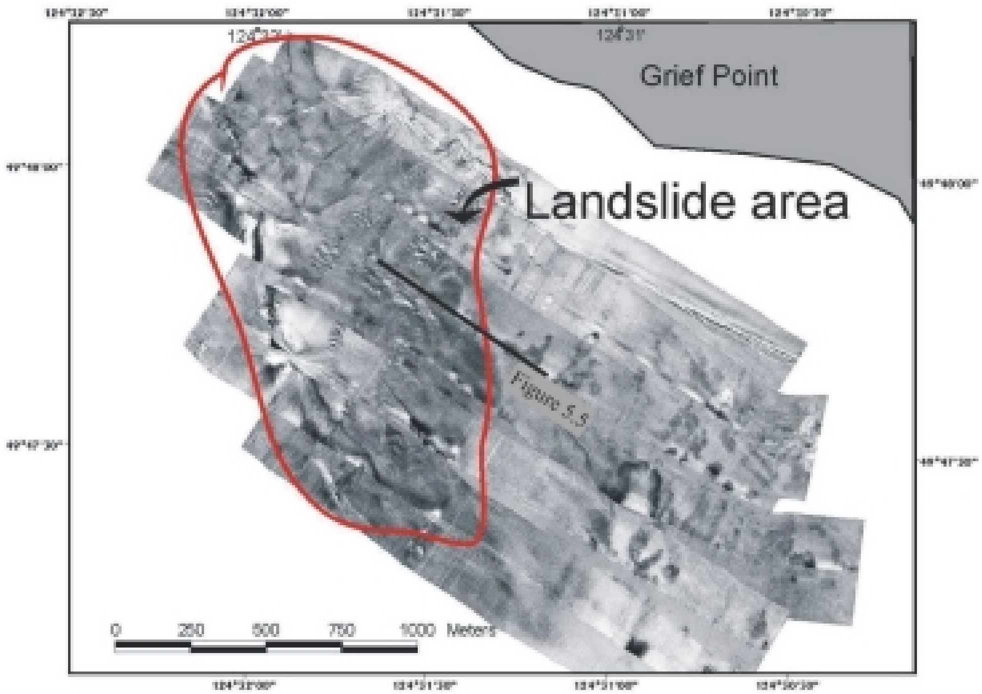


Figure 5.3 Sidescan sonar mosaic of the Grief Point landslide. Water depths range from 20 m in the north to 220 m in the southwest area of the image (from Mosher et al. 2001).

Recent efforts have focused on the development of interferometric systems, which use phase comparison between two or more vertically-spaced receiving elements in the sonar transducer to produce swath bathymetric measurements. Given the similarity between these systems and side scan sonar arrays, signal output can also be presented in a manner similar to a sidescan sonogram (GeoAcoustics 2000; Geen 1999).

5.1.3.4 Acoustic Seabed Classification

Both sidescan sonar and multibeam bathymetry systems provide measurements of acoustic backscatter, or seabed reflectivity. Measurements are displayed as two-dimensional images, or sonograms, of the sea floor. The sonograms are then visually interpreted by an experienced marine geoscientist in order to determine the material composition of the seabed (e.g. soft mud, sand and gravel, bedrock, etc.) and the nature of sea floor morphological features. The process is extremely qualitative and relies heavily on the expertise of individual interpreters.

In recent years, quantitative methods have been developed to characterize the composition and complexity of the seabed based on measured properties of the acoustic return signal from existing bathymetric and sidescan sonar systems. Pioneered for use with single-beam echosounders, acoustic seabed classification systems analyze a suite of characteristics of the return signal to statistically group the surveyed seabed into a number of distinct classes. Each class represents a unique combination of physical and biological characteristics. Maps of the survey area can then be developed showing the spatial extent of each class, representing the acoustic diversity of the sea floor. An example is shown in Figure 5.4, for the Race Rocks Marine Protected Area to the west of Victoria, BC.

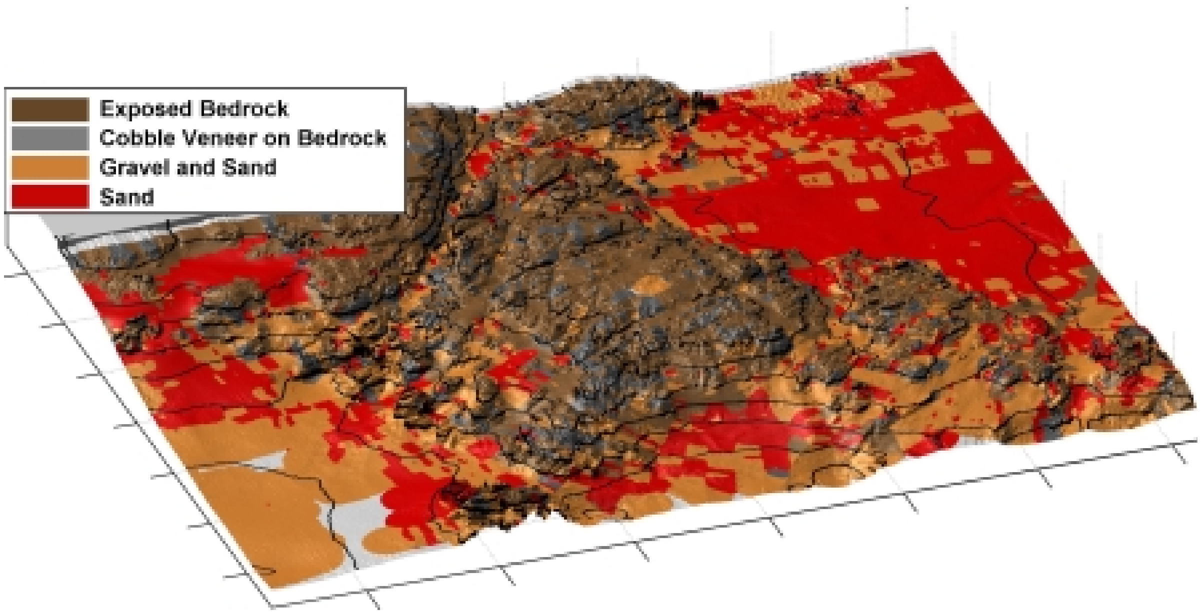


Figure 5.4 Multibeam bathymetry and acoustic seabed classification from single beam echosounder for Race Rocks, British Columbia (from Quester Tangent Corporation 2000).

While acoustic seabed classification systems do not directly measure traditional index properties of the seabed (e.g. sediment grain size, bulk density, etc.) or morphological characteristics (e.g. bedform height and spacing), changes in acoustic class do represent changes in the combination of these and other parameters. As for other mapping tools, ground-truthing is required.

Seabed classification has received recognition as a habitat mapping tool (Smity *et al.* 2001), and can be used as a preliminary survey tool to select sites for in situ seabed investigations. Acoustic seabed classification has been accepted as a reliable method for mapping seabed diversity by the scientific community, and the Canadian Hydrographic Service has proposed that it become a component of operational hydrography. Acoustic classification is only now being adopted for commercial applications (Bill Collins, pers. comm.). Ongoing research into acoustic seabed classification is being conducted through the Canadian Acoustic Remote Sensing Facility (C-MARS) at the University of Victoria (http://www.c-mars.ca).

5.1.3.5 High Resolution Seismic Profiling

Multibeam and sidescan sonar systems give two-dimensional, plan views of the sea floor. High resolution seismic profiling methods are used to view the seabed as two-dimensional, vertical slices, allowing subsurface definition of features such as faults, historic failure surfaces, subbottom horizons and gas-charged zones. These methods use low-frequency acoustic signals from a variety of source types (pingers, boomers, sparkers, airguns and water guns), so as to allow signal penetration into the seabed. Changes in acoustic impedance within the seabed cause partial reflection of the signal back to the source, allowing depth below the seabed of the reflecting surfaces to be calculated. High resolution seismic profiling methods typically use higher frequencies than those used in deep seismic work (Section 5.1.1), permitting the near-surface seabed structure to be mapped in greater detail, but reducing the extent of signal penetration into the seabed (see Terra Remote Sensing Inc. 1999 for a more detailed description).

As for sidescan sonar systems, the basic technology behind these systems has remained relatively unchanged in recent years. The major advancements have been in the digital processing and post-processing of the signal, allowing for easier interpretation of reflectors and sub-bottom features. Figure 5.5 shows a high resolution seismic profile (Huntec Deep Tow System) transecting the landslide deposit shown in Figure 5.3.

Towed three-dimensional sensor arrays are not used in high resolution seismic profiling, since the required sensor spacing, as determined by the signal frequency, is not generally achievable under marine conditions. The use of geophones placed at the sea floor to measure shear waves is a topic of current research (Philip Hill, pers. comm.).

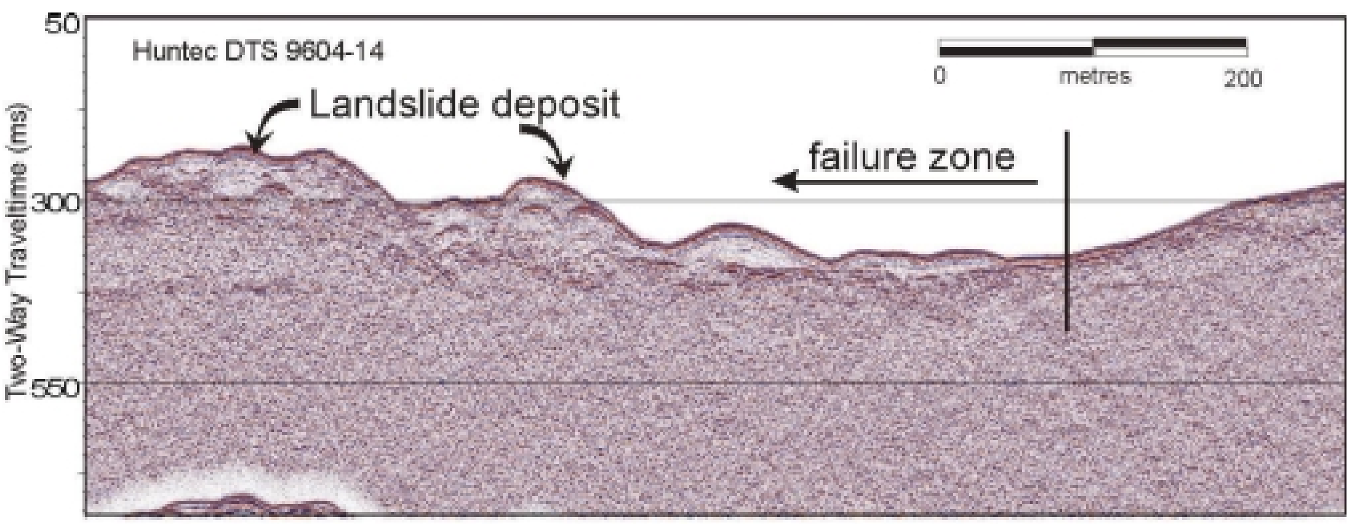


Figure 5.5 High resolution seismic reflection profile crossing the Grief Point submarine landslide.

5.1.3.6 Visual Observations

Visual observations of the seabed are invaluable for a number of uses, including the ground-truthing of geophysical survey information, the collection of additional surficial textural and morphological data, the assessment of sea floor habitat and the identification and enumeration of plant and animal species. Figure 5.6 shows an image of a sponge reef in Hecate Strait.

Figure 5.6 Sponge reef in Hecate Strait.

Seabed images can be collected from frame-mounted cameras dropped over the side of a ship, from still or video cameras mounted on a "fish" towed behind a ship, or from remotely operated or autonomous underwater vehicles. Remotely operated vehicles (ROVs) are controlled through a cable system connected to a surface support vessel, but can move independently of the surface vessel and are routinely used for route survey work. Autonomous underwater vehicles (AUVs) can operate independently of surface ships, but are still considered to be in the development phase. Submersible vessels, available for specialized projects, are generally too expensive for use in routine survey work.

Samples of seabed sediments are collected for a variety of uses including measurement of engineering properties and indices, chemical analysis and biological assessment. Shallow sampling near seafloor is generally carried out using weighted core tubes dropped from a distance above the seafloor. If deeper sampling is required casing is lowered from a drill-ship so that a hole can be drilled to the required depths for intermittent sampling of soil and rock through the casing.

Recent advancements in seabed testing have been primarily in the area of in situ testing of geotechnical and acoustic seabed properties, minimizing the effects of sample disturbance encountered in more traditional sampling and laboratory testing approaches. In-situ testing is also more economical than the traditional methods based on sampling and laboratory testing and permits a more extensive sub-surface coverage of the study area in a given field program.

5.1.3.7 Seabed Sampling and In-situ testing

A variety of cone penetrometer tests (CPT) are available for in situ measurements of geotechnical properties of the seabed. In this approach, an instrumented probe with a conical tip is pushed into the seabed at a controlled rate. Engineering indices measured during a CPT can be correlated to soil strength, pore water pressure and resistance to liquefaction. Downhole seismic measurements can also be carried out during a CPT to assess soil behaviour under small-strain conditions.

In pressuremeter testing (PMT), a cylindrical inflatable probe is inserted into a borehole. The borehole can either be pre-drilled or a self-boring probe can be used. After insertion of the pressuremeter into the borehole, the probe is inflated with hydraulic fluid, allowing the stress-strain characteristics of the sediments to be measured in situ. In-situ pressuremeter testing can also be undertaken using a pressuremeter equipped with a cone penetrometer tip. Such a device is called the cone pressuremeter or full-displacement pressuremeter.

5.1.4 Information Technology

Steady and continuing progress over the last few years in information processing, both in terms of speed and volume has dramatically improved the ability of the oil and gas industry to conduct its exploration and development activities in a scientifically-based and predictable manner.

Improvements in signal processing and sensor technology have permitted the process of interpretation of geophysical data from the realm of art to that of science. Hardware and software capabilities have permitted successful exploration, development and production in more and more varied geological settings at reduced risk and greater economic benefit.

Given the increasing importance of industries in the information technology sector in British Columbia, the provincial economy is likely to benefit from the software, hardware and analytical services that may be procured by the oil and gas industry within the province.

5.1.5 Noise Issues in Geophysical Survey and Exploratory Drilling

Seismic survey is one of the loudest underwater noise-source (see Table 5.1). The effect of noise from seismic surveys and drilling on marine fauna has been the focus of intense research in recent years. The following sources provide outlines of these efforts in Australia and the US:

- www.appea.com.au/environment/proj_seismic.html; and
- www.gomr.mms.gov/homepg/regulate/environ/marmam/sperm_research.html.

Table 5.1 Sub-Sea Noise Levels

Noise Source	Max (dB)	Remarks	Reference
Undersea Earthquake	272 dB	M_l 4.0 (energy integrated over 50 Hz bandwidth)	Wenz, 1962.
Seafloor Volcano Eruption	> 255 dB	Massive steam explosions	Deitz and Sheehy, 1954; Kibblewhite, 1965; Northrop, 1974; Shepard and Robson, 1967; Nishimura, NRL-DC, 1995.
Airgun Array (Seismic)	255 dB	Compressed air discharged into piston assembly	Johnston and Cain, 1981; Barger and Hamblen, 1980; Kramer *et al.*, 1968.
Lightning Stike on Water Surface	250 dB	Random events during storms at sea	Hill, 1985; Nishimura, NRL-DC, 1995.
Seismic Exploration Devices	212-230 dB	Includes vibroseis, sparker, gas sleeve, exploder, water gun and boomer seismic profiling methods.	Johnston and Cain, 1981; Holiday *et al.*, 1984.
Container Ship	198 dB	Length 274 meters; Speed 23 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Supertanker	190 dB	Length 340 meters; Speed 20 knots	Buck and Chalfant, 1972; Ross, 1976; Brown, 1982b; Thiele and Ødegaard, 1983.
Blue Whale	190 dB	Vocalizations: Low frequency moans	Cummings and Thompson, 1971a; Edds, 1982.
Fin Whale	188 dB	Vocalizations: Pulses, moans	Watkins, 1981b; Cummings *et al.*, 1986; Edds, 1988.
Offshore Drill Rig	185 dB	Motor Vessel KULLUK; oil/gas exploration	Greene, 1987b.
Offshore Dredge	185 dB	Motor Vessel AQUARIUS	Greene, 1987b.
Humpback Whale	180 dB	Fluke and flipper slaps	Thompson *et al.*, 1986.
Bowhead Whale	180 dB	Vocalizations: Songs	Cummings and Holiday, 1987.
Right Whale	175 dB	Vocalizations: Pulsive signal	Cummings *et al.*, 1972; Clark 1983.
Gray Whale	175 dB	Vocalizations: moans	Cummings *et al.*, 1968; Fish *et al.*, 1974; Swartz and Cummings, 1978.
Open Ocean Ambient Noise	74-100 dB (71-97 dB in deep sound channel)	Offshore central CA; higher (≥ 120 dB) when vessels present.	Urick, 1983, 1986.

Source: atoc.ucsd.edu/ASTpg.html, see web-page for reference listing

Guidelines have emerged as a result of these research to minimize the effect of seismic survey on marine fauna (e.g., ISR, 2001; JNCC, 1998).

Noise issues on occupational health and safety have also been examined (e.g., HSE, 1999). As a result, it is recognized that the ambient noise exceeds the 90 dB limit applicable in the UK in isolated areas on the offshore oil and gas platform. Exploratory drilling activity is unlikely to elevate the ambient noise beyond 55 dB limits at a distance of 400 m (1,300 feet) from the drilling platform (US DOE, 1999). The workers' exposure to such a high noise level is therefore intermittent. Operational guidelines have developed from these efforts as outlined in CNSOPB (1998) and HSE (1999).

5.2 Drilling Technology in Offshore E&P

Following seismic survey and data analysis, an exploration and delineation drilling program is developed. A local geophysical survey and geotechnical investigation is undertaken around the proposed drilling locations to identify the geological and environmental hazards and risks, as discussed in Section 4, before finalizing the actual location. Exploratory drilling and production can be carried out using one of the following concepts.

Fixed Platforms, which are supported on the seafloor, provide excellent support for offshore oil and gas operations under various weather conditions. Fixed Platforms have been utilized in water depths of up to 1,000 m (3,300 feet) however the costs become excessive as depths increase. They include Jacket Barges and Jack-up Rigs (Figure 5.7).

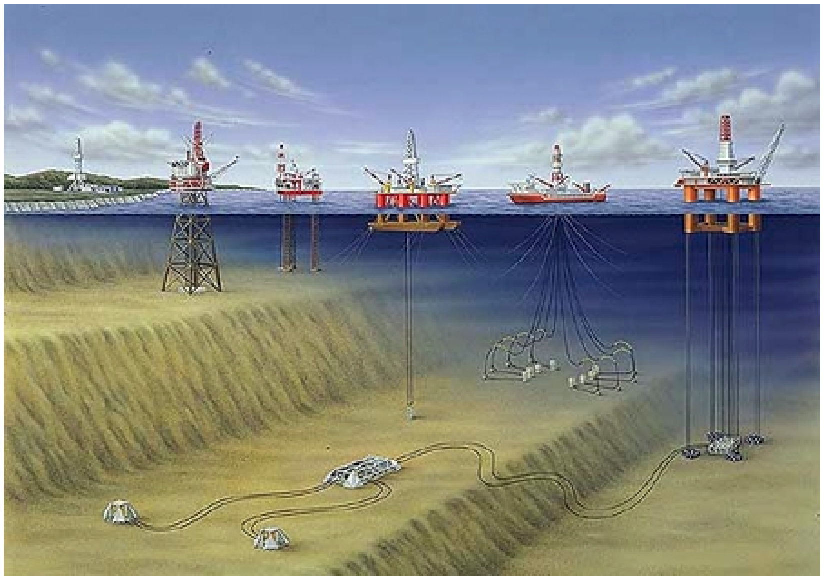


Figure 5.7 Offshore Drilling Units

From left: Jacket Barge, Jack-up Rig, Semi-submersible Unit, Drill Ship, and a TLP with tie-backs

Figure 5.8 Water Depths in the Offshore Lease Areas

For deeper water or heavy loading conditions, large gravity structures have been utilized, e.g., Hibernia and Troll A. A fixed platform is amenable to retrofitting to accommodate changes in load carrying requirements and may therefore provide economical option to address potential future development issues. However, they are affected by seafloor stability and would require special provisions to account for earthquake and other geological hazards, or be located to avoid these problems. A further limitation of jacket barges and gravity structures is decommissioning costs at the end of field life. As shown in Figures 5.8 and 5.9, the water depths in the offshore lease areas around the Queen Charlotte Islands generally exceed 50 m (160 feet). Jacket barges are usually not employed where water depth exceeds 50 m. Such a platform would therefore be unsuitable in many potential target areas. The earthquake and tsunami hazards in these areas are also high. However, fixed gravity structures are being used in areas of high earthquake hazard elsewhere. Hence, this concept may be suitable from an engineering perspective in the offshore areas around the Queen Charlotte Islands in the development and production phase.

The second option is based on Floaters, e.g., Tension Leg Platforms (TLP), Submersibles, Semi-submersibles, Spars, Truss-Spars, Single Column Floaters (SCF), Floating Production Storage and Offloading units (FPSO), and Drill Ships. Figures 5.7 and 5.10 illustrate of some of these designs. These units can be fabricated and transported to the wellhead for installation. The decommissioning of these units is simple. However, these units can only accommodate a smaller number of wells than a fixed platform and are less adaptable to the changes in load carrying requirements because of space constraint and stability issues. This option is likely to be favoured in the exploration phase around the Queen Charlotte Islands.

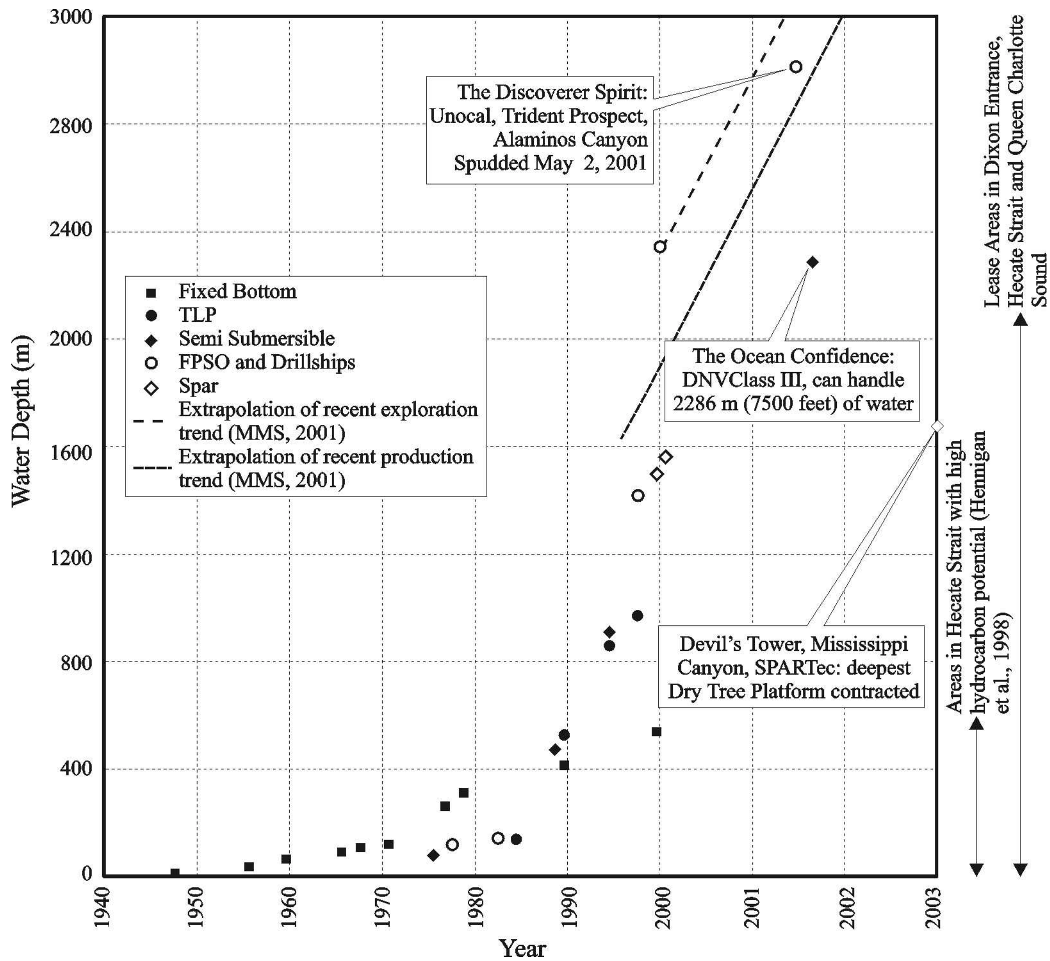


Figure 5.9 Water Depths in the Offshore Oil and Gas Exploration and Production

In subsea completion the wellhead and equipment such as a Blowout Preventer (BOP) stack are positioned on the seafloor and connected to the floating drilling vessel using a "marine riser." Subsequent production operations involve flow lines placed on the seafloor linked to a pipeline system in case of gas or a floating production vessel in case of oil. In a dry-tree concept the wellhead equipment and accessories are supported on a platform above water.

In a conventional drilling program, a large diameter (about 1.1 m or $43\frac{1}{3}$ inch) hole is drilled from seafloor to a depth between 30 and 60 m (100 and 200 feet) and a steel casing (or conductor) of slightly smaller diameter is inserted and cemented in place. Below that depth, a smaller diameter hole (about 650 mm or $25\frac{1}{2}$ inch) is advanced to about 250 m (820 feet) depth and a casing of slightly smaller diameter is inserted and cemented in place. Up to this stage, drilling is generally carried out with seawater and a high viscosity polymer additive for hole-stability and the spent drilling fluid is returned to the seafloor. The BOP stack is then lowered on a marine riser and connected to the wellhead.

After wells are completed they are normally connected to, and operated from, a production facility that can be up to 60 to 100 km (40 to 60 miles) away from the well, leading to significant capital cost savings. These distances are limited by the water temperature (in cold water wax tends to come out of the hydrocarbon and collect on the inner surface of the pipe) and the wellhead pressure. Subsea completion and tieback is based on wet trees installed on the seafloor. An alternative concept is based on a dry-tree system that places wellheads above the well itself on fixed or floating platforms. Dry Completion Units (DCUs) serve as permanent drilling, work over and production units and are deployed in such a development with an FPSO unit (Clarke and Kaalstad 2001).

Figure 5.10 A Truss-SPAR Rig is Being Transported

The BOP prevents blowouts by controlling efflux of formation fluid out of well bore by sealing around the drill pipe. With the marine riser connected, drilling proceeds further with drilling fluid returned to the drill rig for analysis, recycling and treatment. “Zero discharge” drilling can be undertaken from this stage in environmentally sensitive locations (see SCCRWP 1993), which prevents drilling mud discharge into the sea.

Drilling technology has gone through significant advances to extend the reach of offshore exploration and production to greater water depths. The safety and environmental records of offshore oil and gas drilling has also improved significantly over recent years. Table 5.2 lists some of the issues considered during the development of a drilling program. Some of the solutions presented in Table 5.2 have not been fully developed as yet. However these technologies are indicative of the ongoing research and development to minimize risks and maximize the economy of operations. Given the rapid advances in the technology of offshore oil and gas exploration and production, and the complexity of the operations, regulatory agencies should avoid excessive reliance on prescriptive regulations. Such an approach could restrict innovative solutions.

The main advances in offshore oil and gas exploration, delineation and production drilling over recent years include the following:

- horizontal and multilateral drilling;
- slimhole drilling, use of Coiled Tubing (CT), slim risers and casing drilling;
- riser-less drilling;
- advanced mooring and dynamic positioning;
- improvements in BOP, top drive, mud pump and riser design; and
- permissible platform discharges.

These developments are discussed in the following sections. Several other promising technologies, (e.g., seabed drilling) are currently being researched by the industry and are likely to be available commercially within a few years.

Table 5.2 Drilling Issues and Available Technology

Group	Problems	Solution	Capabilities and Limitations
Riser load	Loss of riser and BOP, loss of well, frequent riser disconnects and time-loss, and mud weight limitations	Slim riser	Restricts hole-size
		Lighter riser material	Expensive
		Buoyancy support	Expensive, takes space, increases drag
		Drag reducing fins	Expensive, difficult handling
		Seabed and Riser-less drilling	Are being field tested
Loads on Rig	Stability, weather-related downtime, limited well- and water- depth capability	Riser load reduction	Discussed above
		Dynamic positioning	Expensive
		Fibre-rope mooring	Takes time to install
		Seabed and Riser-less drilling	

Table 5.2 (Continued) Drilling Issues and Available Technology

Group	Problems	Solution	Capabilities and Limitations
Drilling Problems	Riser disconnect	Improved connectors	Increase angle of riser disconnects
		Slim riser	Reduces mud displacement time
		Seabed and Riser-less drilling	Removes pressure on BOP
Well Control	Long-kill / choke lines	Seabed drilling	
	Hydrate blocking of BOP	Injection of chemicals	
	Mud solids settling in riser	Seabed or riser-less drilling	
	Long bottoms-up time (time for fluid return from bit to rig floor) and high mud pressure	Seabed or riser-less drilling or slim riser	
	Shallow gas	Rig selection	Improper rig selection can lead to rig loss (e.g., Petromar 5 in the South China Sea)
		Avoid shallow gas areas	Shallow seismic survey should identify shallow gas areas prior to exploration drilling
		Mud weighting	
		Gas blocking agents in cement, back-pressure while cement is setting and diverter	
Time, cost and impact	Drilling time	Preset Mooring	Reduces seabed disturbance and environmental impact
		Casing drilling (Shepard *et al.*, 2001)	Reduces bore size, decreases mud use and environmental impact
		Twin derrick drill rigs	Cuts trip time significantly. Twin derrick rigs are more common in deepwater drilling.
	Rig day rate	Slim riser	Reduces cost and impact but sacrifices options
		Riser-less drilling	Expensive
	Risk of cost overrun	Slim riser	Reduces cost and environmental impact but sacrifices hole size and options

5.2.1 Horizontal and Multilateral Direction Drilling

Since the post World War II years, directional drilling has become a standard option. Initially the technique was purely used as a means of economically overcoming downhole problems without having to abandon the well and starting with a new well. Since the 1960s it has become a standard oil and gas development planning tool by permitting well drilling from a single surface location to targets thousands of metres away (laterally) from the drilling location. The use of this technique in the offshore areas has allowed operators to avoid the costs of multiple offshore drilling structures. This method has also been used in the last 20 years in subsea completions in conjunction with seafloor-based multiwell templates and associated well control equipment.

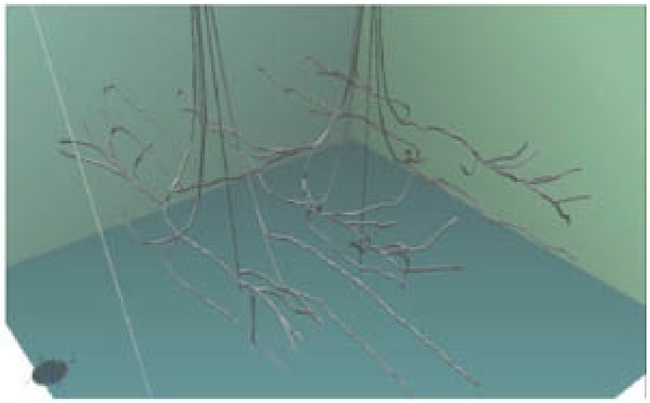


Figure 5.11 Multilateral-Horizontal Wells in the Zuata Field, Faja, Venezuela

More recently multilateral drilling (Figure 5.11) has become available involving drilling a single well bore followed by drilling of several horizontal drainage holes into the sections bearing hydrocarbons to improve the efficiency of oil and gas extraction. Horizontal drilling can overcome geological anomalies such as sealing faults. Proper application of this technology requires considerable knowledge about the local geology and the nature of the hydrocarbon pool. Deviated and horizontal drilling, in order to be successful, require excellent depth control, which is not usually available from seismic survey. Such information can only be obtained from the drilling of vertical exploration holes. Both deviated drilling and horizontal multilateral drilling techniques are widely used in onshore oil and gas developments in northeast British Columbia.

5.2.2 Slimhole and Casing Drilling

The hole-diameter in slimhole drilling is smaller than that in conventional drilling. The advantage of a smaller hole is the reduction in the amount of drilling mud and cuttings. For instance, a borehole with 86 mm ($3\frac{3}{8}$ inch) bottom diameter produces only one-third the volume of cuttings compared to a standard 216 mm ($8\frac{1}{2}$ inch) bore to the same depth. When used with Coiled Tubing (CT), this method typically produce 40 dB noise at 400 m (1,300 feet) compared to 55 dB in conventional drilling. Among the disadvantages of slimhole drilling is the fact that this method limits the options for reservoir control and extraction.

In casing-drilling techniques, casings are installed as the drill-bit advances allowing a smaller hole size as in the slimhole method. This method has similar advantages and limitations as slimhole drilling. Graves *et al.* (2001) describes a recent application of the slimhole technology in the Gulf of Thailand.

5.2.3 Riserless Drilling or Dual Gradient Drilling (DGD)

Among the most significant problems in oil and gas production are those concerning fracture gradients and pore pressures. A relatively small increase in pore pressure or drop in fracture gradient from one drilling section to the next can cause a blowout in the first case or lost circulation in the second. The usual solution is to set casing across the problem zone. However, as a result the hole may become smaller and it may not be possible to deliver the hydrocarbon economically. An alternative approach is a new technology known commonly by the misnomer “riserless drilling” and more appropriately as “dual gradient drilling” or DGD.

During traditional drilling practices, mud is pumped down the drill string, through the bit and up the annulus between the casing and the drill string to the surface. Mud viscosity is designed to carry drill cuttings back to the surface for disposal and the density is such that the natural pressure of the formation can be contained. In DGD, however, the fluids are diverted and pumped via a separate riser to the surface when they return to the seafloor rather than through the annulus. The heavy mud above the seabed, separated from the well bore by the pumps, does not exert influence on exposed formations and, as a result, improves well control.

The DGD procedure developed by Shell replicates conventional drilling in that the drilling fluid is processed to remove large bits of 'gumbo' and cuttings of greater than $^1/_4$ inch before being pumped back via electrical submersible pumps (ESPs). The gumbo and cuttings larger than $^1/_4$ inch are discharged at the seafloor. In contrast, Conoco and DeepVison systems send all returns to the surface with zero discharge. They differ from each other in that Conoco uses seabed triplex pumps, while DeepVison uses centrifugal pumps. The DGD technology is still considered experimental and has not been used extensively.

5.2.4 Advanced Mooring and Dynamic Positioning

Dynamic positioning and the use of preset suction pile moorings are being increasingly utilized in offshore oil and gas developments. Environmentally benign synthetic mooring lines are also being used to a greater extent rather than steel cables. Suction piles for mooring are often installed with a Remote Operated Vehicle (ROV), ensuring minimal environmental impact.

Dynamic positioning systems compensate for the wind, waves and current, allowing a Mobile Offshore Drilling Unit (MODU) to hold position with a maximum excursion of 1 percent of water depth. In other words, if the water depth is 1000 m (3300 feet), a dynamically positioned MODU can maintain position to within 10 m of station. These systems rely on computer control of thruster azimuths, rudders and propellers using inputs from gyrocompass wind sensors, real time Differential Global Positioning System (DGPS), Microwave Positioning System, underwater sonar beacons and hydro-acoustic beacons. Such systems coupled with improved onboard motion compensation equipment allow for safer drilling in deeper water and environmentally sensitive locations.

5.2.5 Design Improvements for BOP, Top Drive and Mud Pump

Recent advances in Blowout Preventer (BOP) design include increased redundancy (4 or more ram cavities), higher pressure rating (100 MPa or more: see www.ansys.com/action/industrial_equipment /stewart.htm) and faster reaction time (some of these models react in 10 to 20 seconds, see www.ntnu.no/ gemini/1993-dec/23.html). Modern marine riser designs include faster connect-disconnect and autoshear mechanisms with the ability to prevent mudflow during emergency shut off. Top drives and mud pumps are becoming available with increasing torque, pressure and power rating. The Ocean Confidence semi-submersible drill rig, for instance, is equipped with four 2,200 hp mud pumps capable of developing 52 MPa (7,500 psi) mud pressure. These developments have made offshore oil and gas exploration and production activities and multilateral drilling feasible in deeper water and have lead to better well control. They have also improved controls and reduced the risk of spill and blowout related environmental impacts.

5.2.6 Platform Discharges

5.2.6.1 Drilling Mid and Discharge of Cuttings

The purpose of drilling mud is to lubricate and cool the drill-bit and flush the cuttings. Drilling muds are water-based (WBM) for shallow exploration (typically up to 760 m or 2,500 feet water depth) and oil-based (OBM) or synthetic-based (SBM) for deeper drilling. In offshore California, the WBM typically consists of (see Appendix B, SCCWRP 1993):

- deflocculating agent: a natural clay called bentonite, 14 to 100 g/l;
- weighting agent: Barium Sulfate or barite ≤ 1.28 kg/l of mud in California;
- thinning agents: lignosulfate derived from low specific heat lignite and sulfate pulping of wood chips (3 to 43 g/l);
- pH and ion control agents (typically caustic soda to maximize deflocculation and to keep lignite in solution); and
- other special purpose additives are also used including cellulose polymers, lubricants, sodium bicarbonate, biocides, mineral oil, and vegetable oil.

Recent research indicates that the environmental impact of seafloor discharge of WBM-laced drill cuttings is limited to 50 to 100 m (165 to 330 feet) from the point of discharge. Although the WBM is relatively environmentally benign, its efficacy is limited in deep drilling requiring the use of a significant quantity of mineral oil in an otherwise water-based formulation. Such a formulation is called oil-based mud (OBM). The residual mud in OBM drilling contains oil. Concerns regarding their toxicity and persistence have lead to regulations that prohibit their seafloor disposal (e.g., California) or impose severe restrictions on allowable oil-content in drill cuttings that may be discharged on seafloor (e.g., the 1997 UK regulation). Environmental concerns about OBMs lead to the development of SBMs based on special chemicals (e.g., ethers and polyalphaolefins) which are relatively non-toxic and biodegrade better than oil additives. However, laboratory experiments indicate that many types of SBM do not degrade at rates much different from OBM.

Consequently, limiting or eliminating discharge of all non-WBM laced cuttings on seafloor is a recent focus as discussed in Section 6 in greater detail. The use of OBM and/or SBM is however expected to continue but the cuttings will either be injected into an underground formation offshore or brought back to shore for treatment and reuse or disposal on land (see UK Offshore Operators Association 1999 Environmental Report at www.oilandgas.org.uk/issues/). The following on-line resources provide synopses of regulatory environments regarding drilling muds in many jurisdictions:

- www.bakerhughes.com/inteq/Fluids/environmental_affairs/; and
- www.offshore-environment.com/drillingwastecontents.html.

5.2.6.2 Miscallenous Acqueous and Atmospheric Discharges

Oil and gas are always found in conjunction with formation water and the oil and gas bearing formations are almost always underlain by formations that are 100 percent water bearing. Water is therefore frequently produced with hydrocarbons (Production Water). In case of gas pools, the interstitial formation water usually constitutes a very small proportion of production, but water vapour mixed with gas will normally condense out as pressure decreases. Such condensation water is not saline. Water discharges are therefore not commonly a big concern for gas pools.

The production of oil tends to be accompanied by the production of saline water. The volume or produced water increases as the pool is depleted with time. Disposal of such water may be problematic if it is not compatible with the seawater of the area. In offshore oil and gas developments the produced water is usually re-injected into the formation that produced the oil. Re-injection usually assists in maintaining reservoir pressure. If re-injection is not appropriate an alternative formation suitable for water disposal is identified.

When oil production is stored offshore before it can be transported to shore by a shuttle tanker, the storage tank cannot be emptied of oil without admitting seawater. The storage tank cannot be filled without expelling the seawater (Displacement Water). Construction of an oil pipeline to shore, if economical, eliminates this problem.

Disposal of produced water and displacement water has to comply with strict regulatory limitations in terms of hydrocarbon content.

Other aquatic discharges may include:

- wash and drainage water;
- sewage and sanitary waste;
- spills and leakage; and
- cooling water.

Primary sources of atmospheric emissions may include (composed mainly of carbon dioxide, carbon monoxide, methane, volatile organic carbons and nitrogen oxides):

- flaring, venting and purging gases;

- combustion processes (e.g., engines and turbines);
- fugitive gases from loading operations and tankage; and
- losses from process equipment.

A survey of international practice and law on these emissions can be found at the following UN Energy Program web-site: oef.unep.ch/management/PaperLegisl.PDF. As discussed in Section 6.1.5, in general these discharges are very small relative to the ocean environment.

5.3 Development, Operations and Decommissioning

Successful discovery of recoverable hydrocarbon reserves may lead to the development of the oil and gas field. Pre-production development activities include the following:

- detailed geophysical surveys;
- local geological hazard evaluations (See Section 4: includes shallow geophysical surveys, getechnical investigations and oceanographic measurements);
- engineering design of the well system;
- engineering design of the production and offloading facilities; and
- fabrication, transportation and installation of these facilities.

A development decision is usually based on limited knowledge. For instance a development decision may be made after the completion of 3 or 4 exploration wells over 2,000 to 4,000 hectare (5,000 to 10,000 acre) area depending on the size of the pool. Uncertainty in the estimated volume of hydrocarbons may be ±50 percent at this stage. A decision is then taken to determine the number of wells that will be required to exploit the reserve. If the number of wells is small there is a large risk that the recovery will be uneconomically low. An attempt to minimize the techno-economic uncertainty by drilling more appraisal wells before development commitment sets back the development time frame and depresses the present worth of the project. Such a strategy also increases the initial investment. Changing the development parameters after project commitment is made adds to the costs and delays in commissioning. This can lead to added exposure to economic risks of currency fluctuation, inflation and commodity prices.

The project decision therefore needs to take into consideration:

- A margin of potential error measured by risk analysis. An appropriate margin in the economic parameters such as target internal rate of return for the proponent and government share (royalty);
- Recognition of opportunities the development offers in long-term spin-off benefits to the province in terms of niche industrial development opportunities;
- Work force training requirements and local employment opportunities;
- A process of rapid development plan adaptation as the information gaps become defined. The development plan should therefore have flexibility and may include for example the possibility of the wells being drilled in a different manner than was originally envisaged;

- Anticipation of continued investment in additional facilities, including facilities to bring on stream marginal satellite hydrocarbon pools as production begins to decline and processing capacity becomes available; and
- Early recognition of the costs of proper decommissioning of the facility.

At the early stage the development parameters should consider known and unknown environemntal conditions. The generic databases would be augmented for the area to be developed by site specific data collected during the exploration phase. It is not uncommon to position a platform and its cluster over a pre-existing well location. Occasionally, an exploration well may even be used in a subsequent production phase.

After the number of wells has been determined and the reserve per well has been estimated, site-specific environmental and geotechnical information are obtained for system design and risk management. Depending on the development options under consideration these activities are may include:

- Site-specific geotechnical and geophysical data acquisition;
- Geologic hazard assessment based on historical hydro-meteorological observations, earthquake activity and soil stability;
- Assessment of risk acceptable to the stakeholders and regulators: experience from a jurisdiction with physical and environmental issues similar to British Columbia offshore can be of use in developing the acceptable level of risk;
- Development of a risk-based design for production, offloading and piping facilities;
- Development of risk-based operational procedures; and
- Development of contingency measures (spill protection, accidents and force majeure): these should include a collapse state design for the Maximum Credible Design parameters, e.g., the Maximum Credible Earthquake (MCE) applicable in the area of development. Under such extreme loading, the facilities should allow a rapid shut down and evacuation to minimize the impact on environment and preclude loss of life. Passive strategies such as avoidance of problem locations (such as potentially active faults) also significantly enhance system reliability.

The regulatory approval process should also consider the estimated risk associated with the operation of the offshore oil and gas development and whether it is within the tolerance of the stakeholders. A procedure should also be in place to facilitate the participation of local industry in the development activity.

The decommissioning activities would include obtaining the necessary permits and clearance, plugging the well, ridding the structures of hydrocarbons, removing the platform and clearing the site. These costs are typically borne by the lessee (see, e.g., Sanders 1998). A number of offshore oil and gas operations in California and the Gulf of Mexico (GOM) have come to the end of their commercial lives. A number of the old platforms in the GOM have been converted to artificial reefs and are managed by the Park Service. They attract large schools of fish and are very popular attractions for recreational fishing and scuba diving. A considerable experience is therefore in place regarding the fundamental issues (see, e.g., MMS Report 98-0023). Consultation is in progress on issues including whether the offshore structures can remain in place and function as an artificial reef, who would bear the liability if such a strategy is adopted, what variety of marine life is attracted by such reefs and relative benefits to commercial and sport fisheries.

5.4 Performance and Risk

5.4.1 Earthquake Risk and Performance

Risk based earthquake design is used routinely in civil engineering for operational basis design. Such a methodology involves estimation of a probabilistic earthquake from historical seismicity of a given area that has a probability of exceedance associated with a risk level that the stakeholders and regulators deem acceptable. Such an earthquake is called the Operational Basis Earthquake (OBE). The offshore oil and gas facilities are then designed so that under the OBE, they remain operational with a minimum need for maintenance and repair and no accident. See, for instance, Carr and Preston (1999) for an application of such a design procedure for a deepwater gas pipeline. Although, the current state of practice uses the 1 in 1,000 year earthquake as the OBE (Iwan *et al.* 1992; see also www.mms.gov/tarprojects/171.htm), the assumption could be modified depending on the risk tolerance of the local regulators and stakeholders. A more severe loading (MCE) is assumed to design the facilities for collapse contingencies as discussed in Section 5.3.

Computer programs are used to analyze the critical fixed, floating and submerged components of an offshore oil and gas facility, for earthquakes representative of the OBE and the MCE, to check system reliability and identify failure modes. The structural systems are similarly checked for the anticipated ground movements related to liquefaction, slope-stability and hydrodynamic effects (e.g. tsunami) if appropriate. These results are then used to minimize or manage earthquake-related risk (see Section 5.4.5).

Such a design philosophy has been adopted over the last decade in design of offshore oil and gas facilities in seismo-tectonic environments similar to or more severe than those in British Columbia offshore. For example, for the design of the existing oil and gas platforms in offshore Azerbaijan, an M8 earthquake was assumed as the Operational Basis Earthquake (OBE). The more recent design philosophy in that area involves use of an M10 event as the MCE. The Molikpaq stationary production platform was designed for an M7 event as the OBE. These structures have not experienced an earthquake as severe as the OBE. However, a few case histories are available in which fixed offshore oil and gas facilities withstood significant earthquake events satisfactorily (Table 5.3).

As discussed earlier, the technology is available to identify potentially active faults and unstable soils and locate offshore oil and gas facilities away from these areas, if the estimated ground movement can not be economically accounted for in design.

Table 5.3 Performance of a few platforms in earthquakes

Platform	Date of event	Water Depth	Magnitude	Damage
Ekofisk	May 7, 2001	76 m fixed	4.2	None reported
Chirag 1	Nov 25, 2000	120 m twin jacket	6.3	None
Tyonek	Several	46 m fixed	> 5	None
California	Jan 7, 1994 (Northridge)	33 m fixed	6.7	MMS reports no damage, 1 small spill

5.4.2 Spill

Available data up to 1985 indicate that urban and industrial wastes and vessel operations account for 37 percent and 33 percent of oil in sea, respectively (Figure 5.12). About 7 percent of oil in the sea is due to hydrocarbons seeping naturally out of fissures. Such oil seeps are observed at a number of locations in the Queen Charlotte Islands. About 9 percent is absorbed from the atmosphere. About 14 percent of the oil in the sea is directly attributable to the oil industry, 12 percent of which is due to accidents involving oil tankers and the remaining 2 percent from offshore oil and gas exploration and production activities.

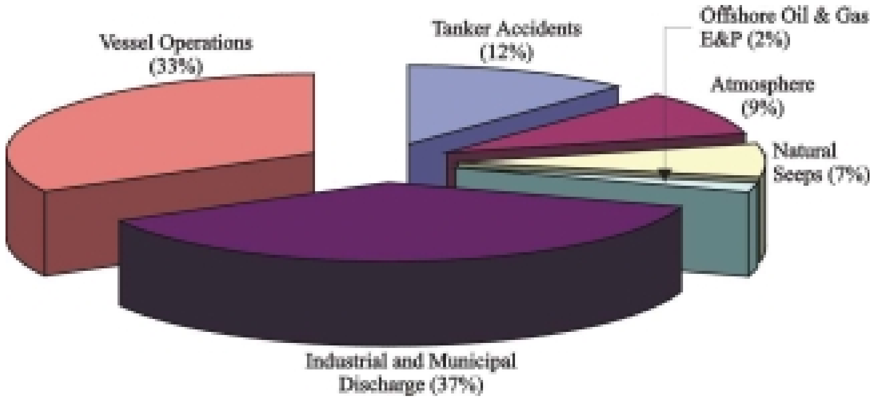


Figure 5.12 Oil in the Sea

Recent data indicate that spills larger than 50 barrels have decreased considerably over the years (MMS 2001). For offshore platform operations, 34,047 spills of 50 barrels or more were reported in the US Outer Continental Shelf (OCS) between 1964 and 1984 for every billion barrel of oil handled. The corresponding number between 1985 and 2000 was 821. Major causes for spills larger than 1,000 barrels in US OCS operations is presented in Figure 5.13. MMS reports 17.5 barrels of spill per million barrels of oil produced in the US Federal Lease Areas in 1999 and has a target of reducing the figure to 5.05 by 2001 (MMS, 2000).

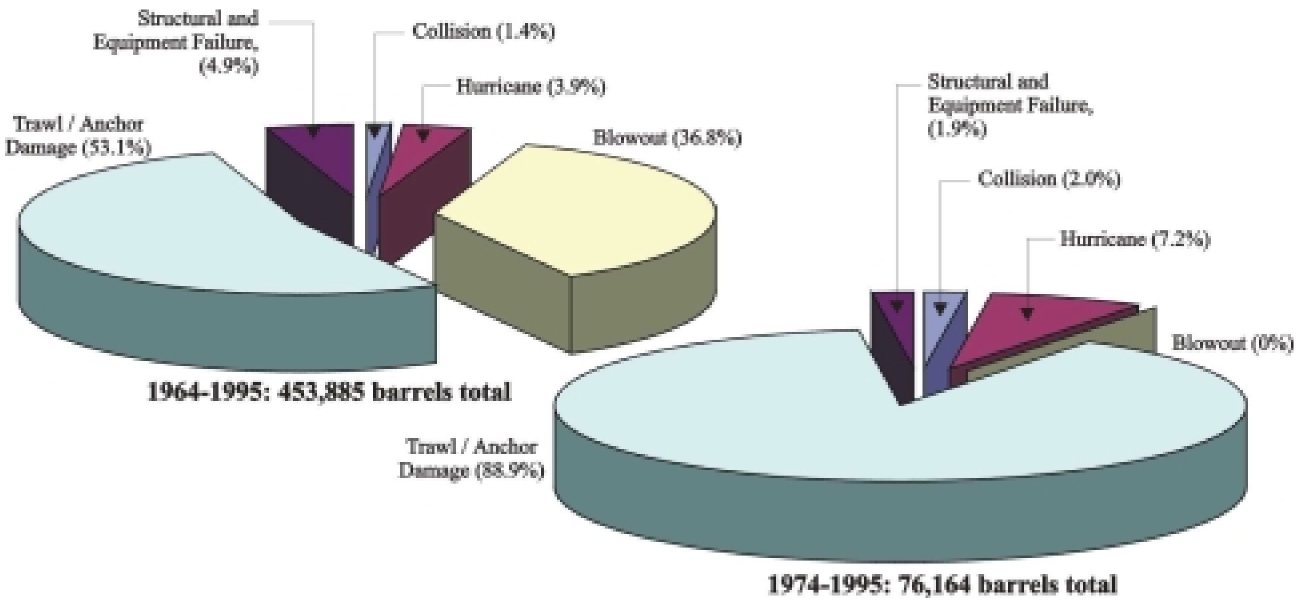


Figure 5.13 Causes of Large Spill in US OCS (based on MMS, 1997 data)

The majority of offshore exploration and production wells in Canadian waters are drilled using SBM. Available information on the E&P activities since 1997 in Newfoundland and Nova Scotia indicate that the spillage-related discharge from offshore operations are about six orders of magnitude smaller than the production volume (see Table 5.4).

Table 5.4 Canadian Offshore Spill Data

Year[1]	Spill in m^3		Production in m^3		
	Exploration	Production	Oil	Gas	Water
1997-1998	4.00	4.00	0.76×10^6	0.16×10^6	0.13×10^4
1998-1999	0.10	4.00	4.10×10^6	1.06×10^9	Not reported
1999-2000[2]	5.60	5.20	6.05×10^6	1.88×10^9	1.48×10^4
2000-2001	0.16	8.43	8.39×10^6	2.39×10^9	20.07×10^4

Notes. 1. From the Annual Reports of the CNOPB.
2. Includes information contained in CNSOPB Annual Report of 1999-2000.

Three major contributors to the spills in Atlantic Canada offshore are:

- SBM spillage;
- overflow from platform open drain system; and
- hydrocarbon spillage due to flare malfunction.

The necessity of strict control of the well circulatory system and a close scrutiny of deck drains and flare design is therefore apparent. A design review of deck drains was undertaken by CNOPB (CNOPB 1999). The available spill containment system could not be deployed in many cases due to inclement weather (CNOPB 1998; 1999; 2000). However, these accidents did not affect the local fauna noticeably.

The Production Water is typically routed through hydro-cyclones and air-stripping systems to ensure the hydrocarbon content of formation water discharged into the sea is below regulatory limits. The regulatory limit for hydrocarbon content for materials that can be discharged in sea is typically 30ppm. This limit needs to be addressed in connection with potential impacts on the environment in British Columbia offshore.

Undersea oil and gas pipelines are wrapped in corrosion resistant coatings and occasionally buoyancy resistant concrete coatings, both of which reduce the risk of spills. Spills related to pipeline operations in the US Outer Continental Shelf (OCS) have registered improvement, albeit not as dramatic as those related to platform operations. Between 1964 and 1984 their operations resulted in 34,874 spills of 50 barrels or more per billion barrel of oil handled. The number declined to 9,122 between 1985 and 2000. As discussed in Section 5.4.5, these systems can be designed for a level of risk that the stakeholders and regulators deem acceptable.

5.4.3 Blowout

All oil and gas located underground is at high pressure. If the natural ‘formation’ pressure exceeds the pressure applied by the column of drilling mud in the drill casing, there will be an uncontrolled flow of oil or gas from the wellhead into the surrounding environment. Such an accident is known as a blowout. During exploratory drilling, gas may also flow from pockets penetrated before the intended reservoir is reached and before wellhead prevention equipment is installed. This is known as a shallow blowout.

The drilling activity for the production phase takes place after a considerable amount of exploratory geophysical surveys and geotechnical investigation has taken place. Consequently, the risk associated with production drilling is lower compared to those in exploratory drilling. Worldwide data indicate that the probability of blowouts is higher during exploration drilling than during development drilling: 1 shallow gas blowout per 200 wells during exploration against 1 per 500 wells for development (see oef.unep.ch/background/bgnote.htm). During production, the frequency of blowout drops sharply; there is an average of 1 blowout per 1000 well before production, with this figure dropping to 1 per 20,000 wells for oil and 1 per 10,000 wells for gas during production.

The only recorded blowout in Atlantic Canada occurred in 1984 at the Uniake-G72 Well off Sable Island involving only 1500 barrels of condensate (The Maritime Award Society of Canada 2001). Twelve blowouts have occurred between 1986 and 1995 in exploration activities in offshore US Federal lease areas. The corresponding figure for the development activities is 15. As illustrated in Figure 5.12, blowout was a significant cause for large oil spills in US OCS prior to the 1970's. However, the historical spill data indicate that the contribution of blowouts to large oil spills is declining remarkably with no spill larger than 1,000 barrel ascribable to a blowout since 1970 in Federal lease areas. Only one blowout-related spill of magnitude greater than 1,000 barrels has been reported since 1988 in the entire US offshore oil and gas operations. A production well blowout in September 1992 caused a spillage of 11,500 barrels in Louisiana State waters.

Seismogenic and biogenic gas is known to be present in many offshore locations in British Columbia. However there is a considerable experience of carrying out drilling and exploration in the presence of shallow gas (e.g. South China Sea and offshore Sumatra). Operational procedures have evolved in Canada in recent years to minimize these risks. For instance, the CNSOPB stipulates use of a 254 mm (minimum) diameter diverter system in the Sable Island operations to address the issue (collections.ic.gc.ca/sable/envoffsh.htm). MMS (1995) also outlines the available well-control options while drilling in shallow gas areas and describes the recent research undertaken in the US on this topic.

There is a significant benefit to the operator of the facility to reduce or minimize the potential for well blowouts. Cost implications related to blowouts provide huge incentive to minimize their potential.

5.4.4 Miscellaneous Accidents

Miscellaneous accidents include trawl and anchor damage, collision and structural and equipment failure. Of these, trawl and anchor damage continues to be a major contributor to large marine oil spills. Consequently, many jurisdictions do not allow navigation within a certain distance of an offshore oil and gas facility. In Atlantic Canada boat traffic and fishing are normally excluded from within 500 m of a drilling rig or production platform, or 50 m from its anchors, whichever is greater (CEF Consultants Limited 1998). The CNSOPB Sable Island operations do not allow anchoring of vessels within 200 m (656 feet) of any submarine pipeline. Drill stem cut off and pipeline layout should be finalized in a manner so as to avoid trawl and anchor damage.

5.4.5 Risk Based Design Procedures

Risk-based procedures are available for designing offshore facilities (see, Vinnem 1999). Procedures, such as Quantified Risk Assessment (QRA), are routinely used in designing industrial facilities for relatively rare natural hazards such as earthquakes and hurricanes. The objective of a QRA is to provide an estimate of the risk of an accident and to compare the probability with the level of risk acceptable to the stakeholders and regulators. A QRA begins with system definition (*i.e.,* a conceptual design of the offshore facility and activities). Hazard Identification is the next stage of a QRA, in which possible accident scenarios are reviewed. The third stage is a Frequency Analysis that involves estimation of the likelihood of a given accident scenario. Previous experience can be used in Frequency Analysis. Alternatively, in the absence of a reasonable body of experience, as is the case in British Columbia offshore, quantitative modeling can be undertaken for the purpose. Parallel to Frequency Analysis, Consequence Modeling is undertaken to estimate the consequence of each possible accident scenario.

After the frequency and consequences of each event are estimated, they are combined to estimate the overall risk. The QRA is also used to identify issues that need special attention in detailed engineering and regulatory review.

5.4.6 Health and Safety Issues

Table 5.5 presents the recent health and safety data from the Atlantic Canada offshore oil and gas industry. These data compare favourably with the industry averages published by the Workers' Compensation Board of British Columbia.

Table 5.5 Occupational Health and Safety

Year	Jurisdiction	Atlantic Canada Offshore Oil & Gas Industry: Lost Time per 100 Person Year	Injury Rate in BC: All Industry Average per 100 Person Year
1997-1998	Newfoundland	2.40 hours	4.4 hours
1998-1999	Newfoundland	2.90 hours	4.2 hours
1999-2000	Newfoundland	2.34 hours	4.1 hours
1999-2000	Nova Scotia	0.85 hours	4.1 hours
2000-2001	Newfoundland	2.55 hours	4.0 hours

Note. Canada Newfoundland Offshore Petroleum Board (CNOPB) and Canada Nova Scotia Offshore Petroleum Board (CNSOPB) report lost time against person hours. Person years were converted to person hours by dividing by 52×40. The British Columbia data are from Workers' Compensation Board of British Columbia (2000).

5.5 Summary

This section has attempted to provide information to the reader that demonstrates the advances in engineering technology as applied to offshore oil and gas developments. The physiological setting in offshore British Columbia, as outlined in Section 4, has been used to assess the relative ability of the industry to provide safe and environmentally acceptable facilities in this region.

While there are some issues, such as earthquake risk, in offshore British Columbia that are more significant than many other regions of the world, some locations can be referenced where similar risks exist. With adequate financial investments to cover appropriate investigations, and adequately designed equipment and facilities, exploration and development activities can result in safe and environmentally acceptable operations.

6.0 BIOLOGICAL/ECOLOGICAL ENVIRONMENT

This section provides a description of the project-related activity/discharge and its interaction with the environment. Possible effects of the project activity/discharge are discussed in terms of key components of the environment (*i.e.,* Valued Environmental Components or VECs (referred to as essential resources and systems in assessments conducted by the MMS)). Information sources include recent environmental assessments as well as primary literature. This chapter focuses on possible effects to the biological and physical components of the environment.

6.1 Issues and Possible Effects

6.1.1 Presence of Structures

Several types of structures may be present during an oil and gas exploration phase. These include mobile offshore drilling units (MODUs) such as semi-submersible or jack-up rigs, drill ships, seismic vessels and support/supply vessels. During the developmental and production phases structures may include gravity based system (GBS) production platforms, floating production, storage and offloading units (FPSOs), and associated subsea structures such as anchors and chains, manifolds, christmas trees, well heads and pipelines.

6.1.1.1 Issues

The primary issues related to offshore structures during the developmental stage include:

- the establishment of safety zones around drilling units and other offshore structures;
- disruption of benthic habitat by subsea structures such as anchors, well heads and pipelines;
- the creation of refuges and artificial reefs for fish and marine mammals;
- the attraction of seabirds to lights and flares; and
- the effects of increased noise on fish, marine mammals and seabirds.

6.1.1.2 Possible Effects

On the east Coast of Canada, the C-NOPB has established the *Newfoundland Offshore Area Petroleum Production and Conservation Regulations* (C-NOPB 2001). Likewise the C-NSOPB has established similar regulations (C-NSOPB 2001). The regulations state that a 500 m safety zone at and under sea level must be established around all production installations and for 50 m around anchor patterns of production installations. Although the regulations state production installations, safety zones are also applied around exploratory drilling units. At the Terra Nova installation on Newfoundland's Grand Banks, four well heads extend for several kilometres from the centralized FPSO. A Fisheries Exclusion Zone (FEZ), totalling 13.8 km^2, has been established. Similarly, FEZs have been established around Hibernia (5.2 km^2) and White Rose (15.4 km^2). The primary concern relating to the establishment of FEZs is the loss of potential fisheries revenue.

6.1.2 Lights and Flares

During drilling and production, natural gas that is present in the oil-bearing reservoir must be released to the surface. The gas may be re-injected back into the reservoir to provide reservoir pressure and enhance oil recovery or it may be flared. Flaring is simply the process of burning off the excess gas in a manner similar to the function of a blowtorch.

Issues

The primary issues related to lights and flares are:

- the attraction of fish and squid;
- the attraction of night-flying or migrating seabirds to the lights and flare; and
- the incineration of birds.

Possible Effects

Although it is generally accepted that fish and squid are attracted to light sources (Hurley 1980), the effects on fish and squid populations are generally considered negligible (Husky Oil 2001b). Light from vessels and flares does not propagate for substantial distances underwater and any attraction would thus be localized to the immediate area surrounding the light source.

One concern related to birds and offshore facilities is that night-flying seabirds and other migrating bird species will be attracted from great distances to lights or flares on offshore installations. Birds that are attracted may experience mortality through strikes against infrastructure or incineration in the flare. Birds may also become disoriented by lights, particularly during overcast or foggy conditions, and fly continuously around them consuming energy and delaying foraging or migration (Avery *et al.* 1978; Bourne 1979; Sage 1979; Wood 1999 (in Husky Oil 2000)).

Bird attraction to offshore platforms has been noted by numerous observers and researchers in the North Sea, Bering Sea and, more recently, on the Grand Banks. Tasker *et al.* (1986) noted higher densities of birds within 500 m of a platform than in the surrounding waters. Following establishment of a platform in the Bering Sea, bird densities were six to seven times higher than densities previously observed in the area of the platform (Baird 1990). Wiese and Montevecchi (2000) also noted a similar pattern in that seabird concentrations around offshore oil platforms on the Grand Banks were 19 to 38 times higher than on survey transects leading to the platforms. As well, there have been numerous observations made and some studies conducted, on bird attraction to land based facilities such as lighthouses, television towers, and skyscrapers.

During surveys of bird attraction to a flare on an offshore platform in the North Sea, it was noted that seabirds (mainly Fulmars (*Fulmarius glacialis*) and gulls (*Larus* spp.)) were attracted to the surface of the sea directly below the flare at night and appeared to be feeding on the surface. However, only one bird was observed flying up near the flame during the five-week observation period (Hope-Jones 1980). During the survey period, no bird mortality was observed from the flare, thus indicating that it is possible for large numbers of birds to be attracted to flares without mortality occurring (Hope-Jones 1980). Other North Sea installations have reported mortality from gas flares, however, the numbers are usually low (Sage 1979; Hope-Jones 1980).

Weather conditions and the magnitude of bird movements are significant factors influencing bird mortality from strikes at tower structures (Crawford 1981). Moisture droplets in the air during conditions of drizzle and fog refract the light and greatly increase the illuminated area thus enhancing the attraction (Wiese *et al.* 2001). These conditions occur frequently at offshore installations on the Grand Banks. Hope-Jones (1980) also noted during observations from an offshore platform in the North Sea, that attraction of landbird migrants (mostly thrushes) to a gas flare occurred more often during misty weather. Of 16 incidents where birds were positively attracted to the flare, 14 occurred during misty or rainy weather.

6.1.3 Discharges

One project-related activity that is of concern to regulators is discharges from an offshore oil and gas platform, most importantly, the deposition of drill cuttings and the dispersion of produced water. Other discharges include ballast water, cooling water, sanitary and domestic waste, and deck drainage. In Atlantic Canada, discharge into the marine environment is governed by the Offshore Waste Treatment Guidelines (NEB, C-NOPB and 1996) (see Section 2.3.1 for differences in application of the guidelines by the C-NSOPB and C-NOPB).

In a recent EIS (MMS 2001a), the MMS identified discharges, including drill fluids, produced water and other discharges as an issue (although not a major issue). It should be noted that it is assumed that the drilling and operational discharges from this Alaskan project would be disposed of on site in a permitted disposal well. If any over the side discharges are permitted (via a National Pollution Discharge Elimination System), it would only apply to marine discharge of treated sanitary and domestic wastewater (MMS 2001a). Other jurisdictions (such as the Pacific Outer Continental Shelf Region and Gulf of Mexico Outer Continental Shelf Region) and elsewhere (such as Western Australia), permit over-the-side discharge of WBM drill cuttings and, in some cases, cleaned/treated (*i.e.,* oil-free) SBM drill cuttings (MMS 2000; 2001b; URS 2001).

6.1.3.1 Drill Cuttings

Drilling muds (refer to Section 5.3.8) are a critical and interrelated part of the drilling operation. The drill muds transport cuttings from the well. Cuttings (or waste rock) are by-products of the drilling process and must be conveyed from the wellbore. In the design of the well trajectory, consideration will be given to the total volumes of drill cuttings generated and the type of drilling fluid used (oil-based, water-based, low-toxicity mineral oil-based or synthetic based). A development would make the attempt to use the most environmentally acceptable fluid that meets the technical criteria of the fluid selection (e.g., direction drilling versus horizontal drilling). Currently, the industry discharges both WBM or SBM drill cuttings over the side, as well as re-injecting OBM drill cuttings into a permitted disposal well.

Issues

The primary issues related to the discharge and deposition of drill cuttings include:

- deposition (smothering habitat, creation of piles, extent of deposition);
- toxicity (based on the chemical constituents of the mud and the fluid and including heavy metals); and
- bioaccumulation (*i.e.,* uptake of hydrocarbons by fish and the perception of taint).

Possible Effects

In shallow areas, the release of drill cuttings may settle on the seabed, affecting the benthic infauna (the focus of most studies, as they are relatively immobile communities; some are pollution tolerant and others, pollution sensitive) in the vicinity of the well. In addition, the drill cuttings may be transported over larger areas, depending on currents and storm events.

While the release of both WBM and SBM drill cuttings can cause potential effects on the environment, there are differences in the level and extent of the various effects. For example, as the WBM drill cuttings are finer than SBM drill cuttings, they have a tendency to spread further in the water column before settling to the sea floor, thus potentially smothering a larger areal extent. While the SBM drill cuttings settle sooner (and have a low solubility in water), they can create piles on the sea floor, thus potentially concentrating any toxic affects of the drill cuttings, or increasing the organic enrichment or the seabed. However, heavy metals in drill cuttings are unlikely to accumulate to levels (or in bioavailable forms) harmful to marine mammals (Hinwood *et al.* 1994 in Husky Oil 2000) or seabirds (Gallagher *et al.* 1999; Husky Oil 2000).

Dose response studies on fish demonstrated that sediments contaminated with cuttings containing a synthetic-cased fluid had a very low acute toxicity potential (Payne *et al.* 2001a; 2001b). However, sublethal effects have been observed in flounder that have had chronic exposure to petroleum-contaminated sediment containing 1 ppm aromatic hydrocarbons (Payne *et al.* 1988).

While bioaccumulation of oil in fish tissue (and subsequent tainting of fish flesh) was identified as a potential issue with the use of oil-based drill cuttings (GESAMP 1993), drill cuttings discharged over the side are either water-based or synthetic-based. A review of the chemicals used in one type of synthetic-based fluid concluded that fish flesh would not become tainted (Kiceniuk 1999).

Another issue with discharge of drill cuttings is the creation of cuttings piles and recovery of benthic communities. North Sea data indicate that biological effects and contamination from single wells may not last beyond one winter storm season (GESAMP 1993). Synthetic-based drill cuttings are biodegradable; the time required for a pile degrade is dependent upon surrounding conditions such as water temperature, bottom currents and aerobic versus anaerobic conditions. Monitoring studies have shown that synthetic-based cuttings have little or no affect on benthic communities outside a radius of 250 m; there is a great variation in diversity of the benthic communities outside 250 to 500 m from offshore installations and effects from drill cuttings discharge are difficult to isolate from natural variation (Jensen *et al.* 1999).

If sediment transport occurs in an area of offshore development, resuspension of drill cuttings by waves and currents, and subsequent deposition, may occur (Husky Oil 2001a).

A study of individual exploration drill sites in the Florida Keys concluded that with the application of modern technology and anti-dumping regulations, exploratory wells could probably be drilled without leaving a trace (Dunstan *et al.* 1991). This conclusion was also supported by an examination of three exploration wells drilled in the Hibernia field that indicated only slight accumulations of drilling materials (NORDCO 1983).

The Offshore Waste Treatment Guidelines currently permit over the side discharge of water-based and synthetic-based drill cuttings, however, offshore developers usually must investigate other disposal options, either on a life cycle cost-benefit basis or a risk analysis basis (Husky Oil 2001b), among others. Disposal options other than over the side of the platform include:

- cuttings re-injection; and
- ship to shore (which has its own on-land alternatives, such as thermal desorption, landfarming, landfilling, *etc*.).

Refer to Section 2.3.1 for the current disposal option preferences of the C-NSOPB and C-NOPB (and parenthetically, the North Sea and Gulf of Mexico).

6.1.3.2 Produced Water

One product from drilling a well is the formation water, which is released as produced water. Production water is initially 100 percent formation water but will eventually become mixed with seawater when the injection water (treated seawater injected to maintain formation pressure) breaks through to the producing well. Produced water can contain hydrocarbons, dissolved mineral salts, sulphur, barium, iron, small amounts of heavy metals and strontium (a naturally occurring radioactive material) and can range in pH from neutral to acidic (Rose and Ward 1981; Thomas *et al.* 1984; Mobil 1985). Due to the high reservoir temperature (110ºC), the temperature of produced water is approximately 60ºC (Husky Oil 2000b).

While water production starts in the first year of operation, the maximum daily amount of produced water usually occurs well into the operating life of a development (e.g., the peak rate of produced water during the White Rose development is not expected to occur until eight or nine years of operation (Husky Oil 2001a)). Produced water must be treated prior to discharge to meet the Offshore Waste Treatment Guidelines total hydrocarbon concentration of 40 mg/L or less averaged over a 30-day period.

Issues
The primary issues related to the discharge and dispersion of produced water are the:

- oil content within the plume (potentially resulting in fish taint and oiled seabirds); and
- temperature of the plume (potentially lethal to some life stages of fish).

Possible Effects
Of the toxic components found in produced water, polycyclic aromatic hydrocarbons (PAHs) are the most persistent and the probable cause of any biological effects associated with produced water (the other toxic compounds evaporate quickly and pose only a very localized threat to marine organisms) (Black *et al.* 1994). PAHs pose the greatest bioaccumulation effect to sessile organisms, such as mussels, with lower concentrations found in crustaceans and lowest in the more highly mobile fish (Neff and Sauer 1996).

Most produced water does not appear to be acutely toxic (Krause *et al.* 1992 in Husky Oil 2000), and is unlikely at a dilution of 25-fold, which will occur near the discharge point (Hodgins and Hodgins 1998). Sessile organisms are most likely to be exposed to the chronic effects of produced water (including accumulation of oil). Sublethal effects have been recorded (Rabalais *et al.* 1992; Raimondi and Schmitt 1992; Krause *et al.* 1992; Din and Abu 1992; Osenburg *et al.* 1992), especially for larval stages of benthic organisms (considered more sensitive to oil pollution than older life stages of invertebrates), as have lowered species diversity and numbers of individuals of benthic invertebrates (Mulino *et al.* 1996). It should be noted that most of the studies were conducted in shallow water or in relation to shallow water situations, and these results may not be transferable to deeper waters in the offshore area (Husky Oil 2000).

Husky Oil (2000) predicted that due to the narrow, snakelike produced water plume that was predicted to occur (through modelling (Hodgins and Hodgins 2000)) on the Grand Banks, and the diluting effect of the Grand Banks, there would be no significant effect on the thermoregulatory capability of seabirds. Those conditions (calm sea state conditions) when an oily sheen could form on the water surface (where seabirds could come in to contact with oil) will rarely occur (probability of less than 1 percent) (Husky Oil 2001a).

The heated produced water should cool to ambient water temperatures within 50 m or less around a production site (Husky Oil 2000), however, some zooplankton and fish larvae (among the most sensitive life stages) in the immediate vicinity of the produced water outfall may be subjected to thermal shock. It should also be noted that the high temperatures may prevent some fouling organisms (such as sessile epibenthic plants and animals) from colonizing some parts of the structure, which helps mitigate the effects of biofouling on a project (Husky 2000).

6.1.3.3 Other Discharges

Ballast Water

Ballast water is seawater used by vessels to provide stability and maneuverability. Generally, seawater is provided to the ballast tanks by a combination of flooding from the sea through valves in the tanks and from the firemain. There are several types of ballast water, as defined by the US Uniform National Discharge Standards, clean ballast, compensated fuel ballast and dirty ballast. Clean ballast water is stored in dedicated ballast tanks and generally does not come into contact with oily substances. Compensated fuel ballast is seawater that replaces fuel as the fuel is used, thereby aiding a ship's stability. The tanks are always full of fuel and/or seawater. Seawater is forced out of the tank during refuelling. Dirty ballast is seawater that is pumped into and out of empty fuel tanks on an emergency basis on some vessels to increase vessel stability. The seawater mixes with residual fuel to produce dirty ballast (UNDS 2001).

Issues

The primary issues related to the discharge of ballast water include:

- release of oily water; and
- introduction of exotic species.

Possible Effects

On floating drill rigs and supply boats, only clean ballast is used. If oil is suspected to have entered a clean ballast system, then under Canada's pollution prevention regulations, which prevent the discharge of oil or pollutant substances into waters under Canadian jurisdiction, water must be tested and treated the ensure that oil concentrations are less than the Offshore Waste Treatment Guidelines of 15 mg/L (NEB, C-NOPB and C-NSOPB 1996).

The effects of ballast water on the environment are generally not related to the release of hydrocarbons, but rather to the introduction of exotic species entrained in the ballast water. Ballast water taken in foreign ports is dumped at the destination port when cargo is loaded and often includes exotic species of plankton, invertebrates and fish. To reduce the entrainment of exotic species, which are generally associated with coastal waters, voluntary guidelines suggest that ocean going vessels originating beyond the limits of the continental shelves replace their ballast with oceanic water when water depths exceed 2,000 m. For vessels not leaving the continental shelves, ballast water should be replaced when water depths exceed 300 m (TC 2001).

MODUs, however, represent a different situation. They remain in one area for extended periods of time and large assemblages of fauna and flora often attach to the subsurface structures, as well as entering ballast tanks. Since they are usually towed slowly from one location to another and may not travel beyond the continental shelves, replacing ballast water while under tow may help reduce the number of exotic organisms being transferred. A recent report by the Australian Department of Industry, Science and Resources indicates that heavily fouled vessels may carry up to 5 kg of material per square metre, or 60 tonnes on average-sized vessels. MODUs may carry greater amounts (Walter 1995 in ISR 2001). Frequent application of antifouling agents may help reduce the transfer of exotic organisms.

Cooling Water

Cooling water is used by vessels and rigs to remove heat from various systems. Seawater is drawn from the ocean either directly, via a hull connection (sea chest), or indirectly, via the firemain pump and passed through a heat exchanger. The seawater is then discharged back into the ocean, usually below the waterline (UNDS 2001). On drilling rigs, cooling water is used for equipment such as top-drives and draw-works.

Seawater is drawn into a closed loop system of heat exchangers and does not contact oily substances. Initially, the water is deoxygenated and sterilized by electrolysis, which releases chlorine from the salt solution (ISR 2001). Concentrations of chlorine are usually less than 2 mg/L (Husky Oil 2000). The temperature of discharged cooling water may be 20 to 30ºC above ambient temperature.

Issues

The primary issues relating to the release of cooling water are:

- the release of chlorinated water into the environment; and
- the increase in water temperature.

Possible Effects

No guidelines currently exist for maximum allowable discharge levels of chlorinated cooling water. However, since cooling water is discharged from a drilling unit’s lower deck, much of the chlorine is lost by vaporization during the fall between the deck and the sea surface (ISR 2001). The effects of elevated water temperatures on the environment from discharged cooling water have yet to be ascertained, but any potential effects are generally considered negligible due to the relatively small volumes discharged.

Sanitary and Domestic Waste

Grey water is sink, shower or laundry water, whereas black water is sewage water. On a typical MODU containing 100 personnel, approximately 40 m^3 and 19 m^3 of grey and black water are released daily, respectively (Mobil 1985).

Sanitary and food wastes are permitted for disposal at sea, however, under the Offshore Waste

Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996), all food wastes must be macerated and reduced to a particle size of 6 mm or less. Degradation of organic waste by bacteria and other small marine organisms is rapid and any effects on the environment from such wastes are generally considered negligible.

All other domestic waste, such as paper, cardboard, plastic or packaging, is not permitted for disposal at sea and must be transported to shore for recycling or disposal.

Issues

The primary issues related to the discharge of sanitary and domestic waste is the attraction of seabirds to disposed food waste.

Possible Effects

While it is generally accepted that gulls and other species of seabirds are attracted to and follow vessels, the effects on birds due to intermittently disposed food wastes are generally considered negligible.

Deck Drainage

Deck drainage is water that reaches the deck of offshore installations through precipitation, sea spray or from routine operations such as washdown and fire drills. Under the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996), the deck drainage system must be completely separate from those systems that collect waste from machinery spaces since machinery space drainage is more likely to come into contact with hydrocarbons. All deck drainage from machinery spaces is routed to skimmers for treatment before discharging. Only water containing 15 mg/L or less of hydrocarbons can be discharged. All deck drainage from non-machinery spaces is released overboard. The effects of deck drainage on the environment are generally considered of low magnitude and of small geographic extent (Husky Oil 2000).

6.1.4 Vessel Traffic

Oil rigs and platforms frequently require support services from dedicated supply vessels. In addition to ferrying personnel, the primary tasks for supply vessels include cargo and bulk re-supply, anchor and mooring chain handling, environmental monitoring, oil spill response, standby service, search and rescue and emergency evacuation (Husky Oil 2000). In the Newfoundland offshore, supply vessels are also used to deflect icebergs away from drilling structures.

Issues

The primary issues related to increased vessel traffic include:

- increased noise and the effects on fish, marine mammals and birds;
- discharge of oily substances and the effects on the environment;

- disruption of migration routed for marine mammals;
- the attraction of seabirds to vessel lighting; and
- illegal discharge of oily bilge water.

Possible Effects

The effects of increased vessel traffic on fish are primarily related to oily discharges and increased noise. As discussed in the previous section, oily discharges from vessels are regulated under the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996) and no vessel may discharge fluids containing more than 15 mg/L of hydrocarbons. The overall effects of oily discharges on fish from vessels are generally considered negligible. Noise in the marine environment is complex and affects different fish species to varying degrees.

Vessel traffic could potentially affect seabirds through vessel lighting (see Section 6.1.2), oily discharges (see Section 6.1.3) and noise. Noise and disturbance from ships are unlikely to affect birds in areas where there is a history of fishing activity and cargo vessel movement. Birds have adapted to vessel traffic and some species, particularly gulls and northern fulmar, are attracted to ships and often stay with them for extended periods (Duffy and Schneider 1984; Brown 1986 cited in Husky Oil 2000). There is a potential for passing ships to disturb seabird colonies, however, prudent seamanship would generally ensure that vessels remain far enough from bird colonies to prevent disturbance.

6.1.5 Atmospheric Emissions

There are four sources of atmospheric emissions generated during exploratory and delineation drilling (Husky Oil 2000):

- burning of well fluids during production tests and well clean-ups (burner boom emissions);
- combustion products (nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM) and unburned hydrocarbons) from engines, generators, heating exhausts, cranes, turbines, helicopters and support vessels;
- mud, degassing and other mudroom exhausts; and
- fugitive emissions.

During the production phase of an oil and gas operation, various other atmospheric emissions are generated including (Husky Oil 2000):

- volatile organic compounds (VOC) from storage tank breathing and filling losses;
- combustion products (nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM) and unburned hydrocarbons) from engines, generators, heating exhausts, cranes, turbines, helicopters and support vessels;
- combustion products (gases) used as an inerting blanket gas in the tanks; and
- flaring operations during well testing or in production upset conditions that emit combustion

products.

Issues

The primary issues related to atmospheric emissions include:

- global warming due to greenhouse gases in the environment; and
- degradation of air quality.

Possible Effects

Global warming due to the release of greenhouse gases was the main focus of the Kyoto Summit in Japan in December 1997. One hundred and sixty countries participated in the summit, which delivered a protocol after 10 days of discussion. The primary aim of the Kyoto Protocol is to reduce greenhouse gas emissions globally by 5.97 percent by 2012. Canada must reduce its greenhouse gas emissions by 6 percent (the Kyoto Protocol was revisited in 2001)(EC 2001). Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), water vapour (H_2O) and chlorofluorocarbons (CFCs). The emissions of primary concern produced by offshore oil and gas installations are nitrogen oxides (NO_x) and reactive organic compounds (ROCs). ROCs or reactive hydrocarbons can react with other chemicals in the presence of sunlight to form ozone and smog and are considered toxic.

Atmospheric emissions from offshore oil and gas installations vary widely according to the project phase and equipment used. A recent study by the MMS (2001b) identified the types and quantity of atmospheric emissions generated by a typical mobile offshore drilling unit, the SEDCO 712, during an exploration and delineation drilling phase. Other sources of emissions measured in the MMS (2001b) study include vessel traffic and helicopters. Daily emissions from a SEDCO 712 MODU and its support equipment operating in Bonito, California are provided in Table 6.1.

Table 6.1 Daily Emissions from a SEDCO 712 and its Support Equipment

Drilling Operation	NO_x (lb/day)	CO (lb/day)	VOC (lb/day)	SO_2 (lb/day)	PM_{10} (lb/day)
Drilling	506.32	67.75	2.85	11.41	22.11
Cranes	23.70	9.21	0.11	0.42	2.65
Flares	70.00	24.50	4.48	2.87	3.50
Total	**600.01**	101.46	**7.44**	**14.70**	**28.26**
Vessels *	241.56	5.78	27.56	97.33	101.33
Helicopter **	12.44	1.78	1.60	32.08	14.26
Overall Total	**854.01**	**109.02**	**36.60**	**144.11**	**143.85**

Source: Modified from MMS 2001b

* Assumes 110 ft crew boat making 8 trips/month, 110 ft supply boat making 12 trips/month.

** Assumes one flight daily.

Air emissions from oil related activities offshore have generally been considered negligible in several of Canada's East Coast oil projects (Husky Oil 2001; Petro-Canada 1995; SOEP 1997) since they are rapidly dispersed to undetectable levels.

6.1.6 Helicopter Traffic

Helicopters are routinely used to carry personnel, equipment and supplies between shore and offshore installations. On the East Coast of Canada, over 25,000 personnel are ferried by helicopter annually to offshore installations (CHI 2001).

Issues

The primary issue related to increased helicopter traffic include the effects of increased noise on fish, marine mammals and birds.

Possible Effects

The effects of helicopter noise on fish generally are considered negligible since sound does not transmit well between air and water. Richardson *et al.* (1995) determined that the frequency of a Eurocopter Super Puma (the helicopter currently being used in the Newfoundland offshore oil industry) flying at 300 m altitude generates frequencies of 20 and 50 Hz. Noise levels detected at the sea surface were 105-110 dB re 1μPa^{-1}, whereas noise levels detected at 3 to 18m depth were 65-70 dB re 1μPa^{-1}. In comparison, wind (<1.8 km/h) generates a noise level of 60 dB re 1μPa^{-1}.

Marine mammals are generally more tolerant of fixed sound sources such as drilling rigs rather than mobile sources of noise such as ships or helicopters. Pinnipeds (seals) are most sensitive to aircraft when they are hauled out for pupping or moulting (Richardson *et al.* 1995). Commonwealth guidelines have been established for aerial observations of marine mammals, which restrict an aircraft from approaching within 300 m of a marine mammal (EA 1999 in ISR 2001). Helicopter flight routes should be selected to minimize or eliminate flights over known haul out areas. Baleen whales, such as minke, right whales and bowhead whales, have been observed changing their swimming behaviour when aircraft have flown at altitudes between 150 to 300 m (Leatherwood *et al.* 1982; Watkins and Moore 1983; Payne *et al.* 1983; Richardson *et al.* 1985a; 1985b). Similarly some toothed whales have also been known to dive or swim away (see Petro-Canada 1995).

Helicopter noise can potentially disturb nesting seabirds at colonies, although seabird reactions to helicopters and other aircraft are complex and depend on a number of factors including species, previous exposure levels, and the location, altitude and number of flights (Hunt 1985 cited in MMS 2001a). Similar to their response to vessel traffic, seabirds may also habituate to air traffic over time. Identification of breeding colonies in an area of helicopter activity and maintenance of minimum altitudes and exclusion zones should mitigate the adverse effects of this activity. Effects to seabirds offshore would be negligible, as aircraft would likely be flying at an altitude and speed that would make any effects to offshore seabirds negligible. Similarly, birds that spend time near offshore installations would become habituated to helicopter traffic (MMS 2001b).

6.1.7 Noise

Noise is generated from operation of the platform and vessel and helicopter traffic, and is discussed in the respective sections (Sections 6.1.4 and 6.1.6).

6.1.8 Seismic Surveys

Seismic surveys are an integral part of offshore oil and gas exploration and are used to determine the existence of potential hydrocarbon deposits buried deep below the ocean's bottom. Specialized vessels tow airgun arrays and hydrophone streamers, which trail the vessel for several kilometres. Airgun arrays consist of small cylinders (10 to 100 cu. in) pressurized to approximately 2000 psi (JNCC 2001) and towed approximately 50 m behind a seismic vessel. Air, which is discharged from the airguns every 6 to 10 seconds with a duration of 10 to 30 milliseconds (ISR 2001), generates a large downward pressure pulse with a frequency between 10 to 300 Hz (JNCC 2001). The high-energy pulse travels through the subsea strata and the reflections are subsequently detected by the hydrophone streamers, which are towed at depths between 5 and 12 m.

Issues
The primary environmental concerns relating to seismic surveys are:

- the effects of seismic surveys on catch rates of commercially important fish species; and
- the effects of high energy pressure pulses on
  - early life stages of fish,
  - swim bladder resonance and ear damage in fish,
  - marine mammal auditory systems, and
  - marine mammal behaviour.

Potential Effects
A study by the Norwegian Institute for Marine Research assessed the effects of seismic surveys on the catch and catch availability of commercially important species of fish such as cod and haddock (Engås *et al.* 1993). Fishing trials using trawls and longlines were conducted several days before, during and after seismic shooting to determine fish distribution and abundance estimates. The overall conclusion of the study was that seismic shooting affected fish distributions in the immediate vicinity and at the edge of the study area, 18-20 nautical miles either side of the shooting area. Trawl catches were reduced by 70 percent in the seismic shooting area and averaged 50 percent over the entire study area, whereas longline catches declined by 44 percent in the shooting area, with no decline observed at the study area perimeter. Acoustic mapping suggested that the fish reacted by swimming away from noise generated by the airguns. The study did not ascertain the duration of effects on fish; however, catch rates remained low for a period of five days after cessation of shooting. It was also suggested that the period of time required to attain normal catch rates following shooting varies with season, locality, duration of

shooting, availability of food and whether fish are migrating.

Few studies have addressed the effects of seismic exploration on ichthyoplankton, or fish eggs and larval fish. Kostyuchenko (1971; cited in ISR 2001) noted that mortality may occur but only in close proximity (approximately 1 to 10 m) to an operating airgun. The Georges Bank Review Panel heard that studies on the potential physical effects of fish and fish larvae are few and not comprehensive enough to provide statistical power, but there was general agreement that within 6 m of an air gun, there were mortalities among eggs and larvae and damage to fish with swim bladders, but there is no significant physical effect beyond the 6 m zone (NRCan and NSPD 1999). There are numerous studies, however, on the physiological effects of seismic exploration on adult fish. Several studies address the effects on fish's swim bladders - air-filled bladders found in most fish, which are primarily used for buoyancy control (for review see McCauley *et al.* 2000). Swim bladders resonate, and the larger the swim bladder, the lower the frequency to which it can resonate. A swim bladder of a large cod is known to resonate at a frequency of approximately 600 Hz (Hawkins 1977; Løvik and Hovem 1979), whereas the swim bladders of smaller fish resonate at higher frequencies. Since seismic testing produces high-energy sound waves below 150 Hz, the effects on swim bladders would be considered slight. However, swim bladder damage and mortality has been observed in adult fish in close proximity (approximately 1.5 to 6 m) to airguns (MMS 2001b).

Low frequency, high-energy sound waves generated by seismic airgun can also affect marine mammals, which depend on low frequency sound waves for communication. The auditory systems of marine mammals are well developed for detecting low frequency sound over many kilometres. Baleen whales, such as grey, right, humpback and fin whales, communicate at frequencies below 3 Hz (JNCC 2001). Toothed whales, such as killer whales, pilot whales, dolphins and porpoises, use much higher frequencies to communicate and their sensitivity to sounds below 1,000 Hz (1 kHz) is poor. A dolphin produces sound with frequencies above 4.8 kHz for communication and may produce frequencies up to 200 kHz for echolocation. Thus, the auditory systems of toothed whales are much less susceptible to the sounds generated by seismic airguns than baleen whales (JNCC 2001).

Comprehensive reviews on the effects of noise on marine mammals were prepared by Richardson *et al.* (1995) and McCauley *et al.* (2000). They conclude that temporary or permanent damage to auditory structures could result if an animal was within 100 m of an airgun array, and that the most likely effects of seismic surveys on marine mammals are to their swimming and feeding behavior. Noise from seismic activity can be heard by whales as far as 50 to 100 km from the source, but avoidance and other disturbance behaviors occur between 5 to 15 km (NRCan and NSPD 1999). Field observations indicated that baleen whales alter their swimming behavior at distance of 5 to 8 km or more (MMS 2001b). Recently, the Joint Nature Conservation Committee (JNCC) in the UK has established guidelines for reducing the impacts of seismic exploration on marine mammals (JNCC 2001). The guidelines suggest that before commencing seismic surveys, the JNCC be contacted for information relating to marine mammal population in the survey area, and that qualified marine mammal observers be placed on seismic vessels during surveys. In addition, the JNCC suggests that visual checks of the survey area be conducted immediately prior to airgun deployment to ensure no mammals are present within a 500 m radius. Slow build-up of power to the lowest practicable power level would provide sufficient time for mammals to vacate the immediate vicinity.

A summary of effects from air gun operations on whales, sea turtles and fish is presented in Table 6.2 (modified from URS 2001).

Table 6.2 Summary of Effects from Air Gun Operations on Whales, Sea Turtles and Fish

Air Gun Level (dB re 1 μPa rms)	**Species**	**Effects**	**Source**
160	Grey Whale	General stand-off range*	Malme *et al.* 1985
150-180	Grey and Bowhead Whales	General stand-off range	Richardson *et al.* 1995
157-164	Humpback Whale	Stand-off range for migrating humpbacks	McCauley *et al.* 2000
140	Humpback Whale	Resting pods with cows in key habitat type begin avoidance	McCauley *et al.* 2000
143	Humpback Whale	Resting pods with cows in key habitat type stand-off range	McCauley *et al.* 2000
179	Humpback Whale	Maximum level tolerated by investigating, probably male, humpbacks to single air gun	McCauley *et al.* 2000
175-176	Loggerhead Turtle	Avoidance	O'Hara 1990
166	Green and Loggerhead Turtles	Noticeable increase in swimming behaviour	McCauley *et al.* 2000
175	Green and Loggerhead Turtles	Turtle behaviour becomes increasingly erratic	McCauley *et al.* 2000
149	Rockfish (*Sebastes* spp.)	Subtle behaviour changes commence	Pearson *et al.* 1992
168	Rockfish	Alarm response	Pearson *et al.* 1992
>171	Fish Ear Model	Rapid increase in hearing stimulus begins	McCauley *et al.* 2000
182-195	Fish (*Pelates sexlineatus*)	Persistent C-turn startle	McCauley *et al.* 2000
200-205	Selected Rockfish Species	C-turn startle responses elicited	Pearson *et al.* 1992
183-207	Various Wild Finfish	C-turn startle response	Warde *et al.* 9n press
Level not determined	Fish (*Chrysophrys auratus*)	Preliminary evidence of pathological damage to hearing systems of contrained fish	McCauley *et al.* 2000
146-195	Finfish	No significant physiological stress increase	McCauley *et al.* 2000

Source: Modified from URS 2001

* General stand-off range relates to the distance these animals will remain from a vessel towing an operating air gun.

Given the ongoing concern on the potential effects of seismic activity during oil and gas exploration, a workshop was held in 2000 to discuss priorities for research on the effects of seismic activity on the East

Coast fishery. Recommendations that resulted from the workshop included (LGL and Griffiths Muecke Associates 2001):

- highest priority, the study of seismic effects on shellfish (especially crab and lobster);
- an ad hoc study of seismic effects on catch rate of cod during coincident seismic activity;
- seismic effects on hearing structures (and hearing ability) in swordfish and tuna;
- duration and extent of seismic effects on cod and redfish catches;
- behavioural and sublethal effects of seismic activity on fish; and
- behavioural study of seismic effects on spawning.

6.1.9 Oil Spills [Accidental Events]

There are five size classifications for oil spills, the top three of which are cumulative (*i.e.,* includes the smaller sized spills) (Husky 2000a):

- extremely large spills - >150,000 barrels;
- very large spills - >10,000 barrels;
- large spills - >1,000 barrels;
- medium spills – 50 to 999 barrels; and
- small spills – 1 to 49.9 barrels.

The five potential sources of an oil spill from exploration activities include (WAEPA 1997 in URS 2001):

- burning-off during production testing;
- refuelling incident;
- diesel storage on rig;
- rupture of fuel tank on tender/supply vessel; and
- blowout (loss of well control due to encounter with unexpected high reservoir pressure).

The most common spills that might occur during the exploration phase of an offshore oil and gas development are small spills (equivalent 1 to 49 barrels). The exploration phase is least likely to have larger spills unless associated with blowouts (Table 6.3).

While small spills can occur during routine drilling and production activities, this section will focus on larger spills that result from an accidental event during development/production (Table 6.4).

Table 6.3 Important Exploration Well Statistics from World-Wide, Gulf of Mexico, Offshore Norway North Sea and UK North Sea

Location	Statistic	Source
Exploration Wells Drilled World-Wide, 1955-1980	11,737	Gulf 1981
Approximate Exploration Wells Drilled World-Wide To 1988	20,000	Sharples *et al.* 1989
Blowouts During Exploration Drilling World-Wide (Including Shallow Gas Blowouts), 1955-1980	96	Gulf 1981
Blowouts During Exploration Drilling World-Wide (Including Shallow Gas Blowouts), 1980-1996	81	E&P Forum 1996
Exploration Wells Drilled, US Gulf of Mexico, 1955-1980	4,794	Gulf 1981
Blowouts During Exploration Drilling (Including Shallow Gas Blowouts), US Gulf of Mexico ,1955-1980	30	Gulf 1981
Exploratory Drilling Blowouts, US Outer Continental Shelf, 1971-1995	49	MMS 1997a
Exploration And Appraisal Wells Drilled Norwegian Offshore, 1966-1980	939	NPD 1999
Exploration Wells Drilled UK North Sea, 1964-1980	838	Gulf 1981
Exploration And Appraisal Wells Drilled UK North Sea, 1988-1997	1,694	Meltzer 1998
Exploration Wells Drilled North Sea UK And Norwegian Combined, 1980-1992	2,315	E&P Forum 1996
Exploration Drilling Blowouts North Sea UK And Norwegian Combined, 1980-1992	16	E&P Forum 1996

Source: Husky Oil 2000

Table 6.4 Important Development/Production Well Statistics from World-Wide, Gulf of Mexico, Offshore Norway North Sea and UK North Sea

Location	Statistic	Source
Development Wells Drilled World-Wide, 1955-1980	24,896	Gulf 1991
Approximate Development/Production Wells Drilled World-Wide To 1988	51,000	Sharples *et al.* 1989
Blowouts During Development Drilling (Including Shallow Gas Blowouts), 1955-1980	66	Gulf 1981
Other Blowouts (During Production, Workovers, etc.), 1955-1980	52	Gulf 19981
Blowouts During Development Drilling (Including Shallow Gas Blowouts), 1980-1996	51	E&P Forum 1996
Other Blowouts (During Production, Workovers, etc.), 1980-1996	73	E&P Forum 1996
Development Wells Drilled In US Gulf of Mexico, 1955-1980	12,390	Gulf 1981
Blowouts During Development Drilling (Including Shallow Gas Blowouts), US Gulf of Mexico, 1955-1980	36	Gulf 1981
Production And Workover Blowouts, US Gulf of Mexico, 1955-1980	32	Gulf 1981
Development Drilling Blowouts, US Outer Continental Shelf, 1971-1995	45	MMS 1997a
Production, Workover And Completion Blowouts, US Outer Continental Shelf, 1971-1995	57	MMS 1997a
Development Wells Drilled, Norwegian Offshore, 1966-1998	1,501	NPD 1999
Development Wells Drilled, UK North Sea, 1964-1980	721	Gulf 1981
Development Wells Drilled, UK North Sea, 1988-1997	3,932	Meltzer 1998
Development Wells Drilled, North Sea UK And Norwegian Combined, 1980-1992	2,389	E&P Forum 1996
Development Drilling Blowouts, North Sea UK And Norwegian Combined, 1980-1992	4	E&P Forum 1996

Source: Husky 2000a

The two types of accidental events that could occur during drilling and operation of an offshore oil and gas platform are oil-well blowouts (continuous spills lasting hours, days or weeks which discharges large volumes of crude oil into the surrounding waters and petroleum gas into the atmosphere) and "batch spills" (instantaneous or short-duration discharges of oil from accidents occurring where the oil is stored or when transferring to offloading vessels) (Husky Oil 2000).

Issues

The major issues associated with an accidental release of oil includes:

- ingestion -- bioaccumulation through the food chain, resulting in lethal and sublethal effects;
- insulation – inability to thermoregulate, resulting in higher energy costs and potentially starvation (primarily seabirds and furred marine mammals);
- irritation – resulting in increased sensitivity to skin lesions/parasitism (primarily fish and marine mammals);
- taint (fisheries);
- buoyancy (seabirds); and
- persistence – if oil reaches land or the seabed, future storm events or land/substrate disturbance can free trapped pockets of oil and re-release them into the environment.

Possible Effects

The short-term effects of oil spills are generally well understood. Depending on the location, time of year, and exposure of animals and/or fish , short-term effects range from sub-lethal (e.g., pelagic fish) to mortality (e.g., seabirds). The longer-term effects (often behavioural and physiological) can last months to years (depending on species, exposure time, spill type). Generally, the recovery time of affected animal populations range from fast (months) (e.g., recolonization by plants and benthic organisms) to slow (years) (e.g., according to some sources regarding seabird colonies).

Fish and Fish Habitat

The effects of oil spills on fish and fish habitat have been studied extensively (see, for example, Armstrong *et al.* 1995 and Rice *et al.* 1996 for recent comprehensive reviews). Oil spills can result in mortality (Berdugo *et al.* 1979; Foy 1982; Trudel 1985), shortened life span and total egg production (Berdugo *et al.* 1979), inhibited or modified feeding behaviour (Berman and Heinle 1980) of zooplankton (a common prey species for many fish, birds and mammals). While oil spilled nearshore can become captured in pockets and be affect benthic fauna for years after a spill (Sanders *et al.* 1990; MMS 2001a), oil from a deepwater offshore spill water will not come in contact with the substrate (Husky 2000a).

Both lethal and sublethal effects of kelp beds (and other marine plants) have been observed, and are a primarily a result of surface oil slicks and soil entrapped in the substrate, However, marine plants can recolonize and recover within a few years (Duncan *et al.* 1993 and van Tamelen and Stekoll 1993 in

MMS 2001a). Ironically, the clean-up of an oil spill can often delay the recolonization and recovery of marine plants, as cleaning an area treated with a high-pressure wash could have as large an effect as the oiling itself (Houghton *et al.* 1996 in MMS 2001a).

Invertebrate (e.g., crustaceans such as lobster) eggs and larvae oil sensitivity varies with species, life history stage and oil type and concentration (Husky Oil 2000). Oil exposure may result in reduced feeding and growth rate and increased oxygen consumption in invertebrate larvae (Johns and Pechenik 1980). Fish eggs and larvae are the life stage most sensitive to effects of oil (up to 10 times as sensitive as adults (Moore and Dwyer 1974; MMS 2001a)) as they cannot easily avoid a spill or depurate toxins from their body and develop at or near the surface where exposure to oil is greatest (Rice 1985). Affected eggs and larvae generally exhibit morphological malformations (Kühnhold 1974; Hose *et al.* 1996; Norcross *et al.* 1996), behavioural abnormalities (Kühnhold 1972) genetic damage (Hose *et al.* 1996; Norcross *et al.* 1996; Marty *et al.* 1997) and reduced growth (Marty *et al.* 1997). With respect to pink salmon smolt (Husky Energy 2000a):

> "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."

Adult fish are mobile and any potential effect from an oil spill is dependent on timing and location (Husky Oil 2000). This is especially true of pelagic fish (living within the water column). Benthic fish (living on or just above the seabed) may be at higher risk in shallow waters if oil reaches the sea bottom and becomes entrapped in the substrate. An oil spill can result in lethal (e.g., direct mortality from suffocation due to oil coating the gills or toxicological disruption of physiological processes) and sublethal (long-term physiological and behavioural) effects (Husky Oil 2000; MMS 2001a). Many fish species can detoxify and excrete harmful oil compounds (Koning 1987) and can also excrete oil through gills and in mucous secretions of the skin (Varanasi *et al.* 1978; Thomas and Rice 1981; 1982). However, heavier hydrocarbon fractions can accumulate in fish tissue, resulting in damage to the liver, gut, pancreas, vertebrae, stomach, brain and olfactory organs and physiological changes in heart rate, respiration, blood parameters and ion concentrations (Rice 1985 in Husky Oil 2000). Other physiological effects include reduced growth (Moles and Norcross 1998), increased viral infections (Carls *et al.* 1998) and lesions (Marty *et al.* 1999) (both found in Pacific herring), and changes in fish health (Moles and Norcross 1998). Behavioural changes in fish may include altered schooling behaviour (Gardner 1975), predator avoidance (Pearson *et al.* 1984) and feeding (Christiansen and George 1995). The most likely potential threat to individual salmon in the event of a large offshore oil spill is contact of the oil with migratory pathways (or spawning habitat, but this is unlikely, given that salmon spawn in headwaters of freshwater waterways) (MMS 2001a). To a lesser extent, salmon could also be affected by potential effects to lower trophic levels (*i.e.,* their food source) (MMS 2001a). In addition, while fish can avoid oil-contaminated water, they may choose not to if they need to migrate to a specific area (Husky Oil 2000):

One such study tested whether adult salmon returning to a home stream avoided a contaminated fish ladder and used and uncontaminated ladder instead. Salmon did avoid the contaminated ladder when concentrations of monoaromatic hydrocarbons approached acute toxic levels (Weber *et al.* 1981)

No conclusive evidence exists to suggest that oiled sites (such as the *Exxon Valdez* areas) posed a long-term hazard to fish embryo or larval survival (Kocan *et al.* 1996 in Husky Oil 2000). The *Exxon Valdez* spill did not significantly affect the larval distribution, settlement, fecundity, recruitment and growth of juvenile and subadult crab, pandalid shrimp, clams and scallops (Armstrong *et al.* 1995). A study on prey sources of juvenile salmon in Prince William Sound concluded that the *Exxon Valdez* spill did not reduce the availability of various prey, including zooplankton (Celewycz and Wertheimer 1996 in Husky 2000a).

Fisheries

The direct effect of an oil spill on the fisheries is fouling of fishing gear and vessels. The primary biological effect of an oil spill on the fisheries is the uptake of hydrocarbons into commercial fish species and tainting (or more importantly, the perception of tainting) of fish flesh. Tainting in marine organisms is defined as “a foreign flavour or odour in the organisms induced by conditions in the water to which the organisms are exposed” (GESAMP 1982), and the off-taste is considered a warning sign that degradation/spoilage of tissue is occurring, especially with regard to fish (Höfer 1998a; 1998b). The principal components of oil that cause taint (such as phenols, naphthenic acids, dibenzothiophenes, mercaptans, tetradecanes and methylkated naphthalenes) are water- and lipid-soluble and are, therefore, readily taken in and absorbed into fish tissue. Fish with high fat content (such as herring) are more susceptible to taint than those with a lower fat content (cod and haddock) (Sidwell 1981); shellfish have relatively low lipid content (Ackman 1976). Even if no tainting occurs, the public perception of tainted fish from an area in or near an oil spill can influence the economic stability of a fisheries, and prices and sales can decline dramatically, even if taint tastes indicate tainting had not occurred (Zitko *et al.* 1984; Tidmarsh *et al.* 1986).

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 in Husky Oil 2000).

Seabirds

Seabirds are the group most at risk from marine oil spills and blowouts, and can experience immediate, short-term and long-term effects:

- immediate effects include external exposure when a bird lands or a diving bird surfaces or swimming bird swims into an oil slick, resulting in a loss of waterproofing, thermoregulatory capability (hypothermia) and buoyancy (drowning) due to matting of feathers (Clark 1984; Hartung 1995; Weisse 1999; MMS 2001a; Weisse *et al.* 2001);
- short-term effects include ingestion of oil from excessive preening/cleaning (of even slightly oiled feathers (Stout 1993)), resulting in lethal (McEwan and Whitehead 1980; Hughes *et al.* 1990; Khan and Ryan 1991; MMS 2001a) and sublethal (Hartung and Hunt 1966; Lawler *et al.* 1978; Holmes *et al.* 1979; Peakall *et al.* 1980; 1982; MMS 2001a) effects, including starvation due to increased energy needs to compensate for heat loss (Hartung 1967; 1995; McEwan and Koelink 1973);
- long-term effects include
  - transfer of oil from plumage and feet of nesting seabirds to eggs and its affects on embryos and hatching and fledging success (Albers 1977; 1978; Albers and Szaro 1978; Hoffmann 1978; 1979a; 1979b; Leighton *et al.* 1995; Macko and King 1980; Albers and Gay 1982; Parnell *et al.* 1984; Harfenist *et al.* 1990; Stubblefield *et al.* 1995),
  - direct ingestion of oil by breeding seabirds and ducklings can result in decreased fertilization, egg laying and hatching, and chick growth and survival (Hartung 1965; Holmes *et al.* 1978; Miller *et al.* 1978; Peakall *et al.* 1980; Vangilder and Peterle 1980; Ainley *et al.* 1981; Szaro *et al.* 1981; Trivelpiece *et al.* 1984), and
  - indirect reproductive failure due to nest and chick abandonment by patents (Butler *et al.* 1988; Eppley and Rubega 1990).

Opinion is divided on whether oil pollution produces major long-term effects on population dynamics or bird productivity (Clark 1984; Butler *et al.* 1988, Boersma *et al.* 1995 and Wiens 1995 suggest there are no long-term major effects, while Piatt *et al.* 1990 and Walton *et al.* 1997 indicate the opposite). There is no direct relationship between the volume of oil spilled and bird mortality, rather it is the timing and location of spills that influence mortality rates (Weise *et al.* 2001).

Marine Mammals

Marine mammals exhibit avoidance and behavioural effects (cetaceans and pinnipeds) (St. Aubin *et al.* 1985; Harvey and Dahlheim 1994; Lowry *et al.* 1994; Matkin *et al.* 1994; Spraker *et al.* 1994; Smultea and Würsig 1995, MMS 2001a), can experience oiling of external surfaces (especially fur of sea otters and fur seals) (Davis and Anderson 1976; Geraci and Smith 1976; Geraci 1990; Sergeant 1991; Lowry *et al.* 1994; Spraker *et al.* 1994; Williams *et al.* 1994; Levenson and Schusterman 1997; MMS 2001a), can digest and inhale oil (especially from cleaning oiled fur) (Geraci and Smith 1976; Engelhardt *et al.* 1977; Engelhardt 1985; Geraci 1990; Würsig 1990; Spraker *et al.* 1994; Bence and Burns 1995; MMS 2001a), experience fouling of baleen (cetaceans) (St. Aubin *et al.* 1984; Geraci 1990; MMS 2001a) and increased exposure from contaminated haulout sites (pinnipeds) (Boulva and McLaren 1979; Yochem *et al.* 1987).

Migrating grey whales were apparently not adversely affected by the *Santa Barbara* spill (Geraci 1990 in Husky 2000a). A review of various whale populations after the *Exxon Valdez* spill could find no evidence of effects on humpback whales in Prince William Sound (von Siegesar *et al.* 1994), and while there was a significant decrease in the size of a resident killer whale pod, no clear cause and effect relationship between the spill and decline could be established (Dahlheim and Matkin 1994).

Summary

The effects of oil on marine resources was summarized in an Australian study on the effects of exploration activities (URS 2001) and are provided for components relevant to the BC marine environment in Table 6.5.

Table 6.5 Summary of Effects of Oil on Marine Environment

Habitat/Population Type	**Exposure and Type of Effect**	**Sensitivity to Oil and Recovery Rates Following Exposure**
Intertidal Mud and Sand Flats	Areas supporting great variety of marine flora and fauna and often spawning or nursery grounds and fish and bird feeding areas. Susceptible to adverse effects	Dependent on the persistence of pockets of oil and the availability of recolonizing species, recovery rates can range from months to years
Birds (Breeding Areas)	Plumage may become matted with oil and oil may be ingested, resulting in mortalities	Birds are very sensitive and an exposed breeding population would likely be slow o recover
Seals and Sea Lion Haulout and Breeding Areas	While seals and sea lions may be able to avoid small surface slicks, the effect on adults and pups onshore may be severe	Haulout areas very sensitive to oiling, especially during and after pupping
Whales and Dolphins	Ability of whales and dolphins to move out of an affected area may minimize the effect	Unknown at sea, with possible high risk to calves during feeding
Reefs (non-coral)	The effects on associated flora and fauna may be sever if the reef is shallow, however, it is unlikely the oil will persist	Sensitivity dependent upon depth and exposure time to slick
Fish	While pelagic fish could avoid the affected area, mortality, tainting and birth defects could occur. The most sever effects could occur on breeding populations in confined waterways and to benthic life stages of fish and crustaceans that occur in areas of highly polluted substrate	Moderate sensitivity and moderate to rapid recovery rates
Benthic Communities	Species composition, abundance and distribution may be affected (thus potentially disturbing the ecological balance)	Mobile species will avoid a slick, non-mobile species may be more sensitive, however, surrounding areas will provide recruitment to aid recovery

Table 6.5 (Continued) Summary of Effects of Oil on Marine Environment

Habitat/Population Type	Exposure and Type of Effect	Sensitivity to Oil and Recovery Rates Following Exposure
Kelp Beds	It is unlikely that oil will persist on the kelp fronds or penetrate surrounding sediments, however, some contact burning may occur of the kelp is emergent	While intertidal algal beds may experience some damage, they quickly recover
Sandy Beaches	The effect could be severe on feeding and breeding wading birds and intertidal fauna	Recovery is dependent on the time required to clean the sandy beach – pockets oil can persist. Breeding populations affected by the spill can be slow to recover
Rocky Intertidal	Due to the usual conditions found in the rocky intertidal zone, the organisms in this habitat are hardy and probably fairly resistant to damage by oil. Some parts of the habitat could experience suffocation or loss of purchase due to surface slickness)	Doe to the environmental conditions usually found in this habitat, the area usually experiences a fast recovery and rapid recolonization.
Open Water	Surface dwelling/diving mammals and birds could be affected if they surface/div through an oil slick	Diving birds usually become oiled, however, most mammals can avoid open water slicks
Fishing	Fishing activities could be interrupted and their could be a public perception of taint of fish caught in or near an oil spill.	While there may be a public perception of taint, analytical data does not usually support actual contamination of flesh fish Effects usually short term.

Source: after AMOSC 1997 in URS 2001

6.2 Mitigation

The industry standard is to incorporate mitigation measures into the design of a program or development (both standard and project-specific) and can include additions to or changes in equipment, operational procedures, timing of activities or other measures. Mitigation includes environmental design, environmental protection strategies and mitigation specific to a particular component of the environment (e.g., seabirds) (Husky Oil 2000). Environmental protection planning incorporates the project-specific mitigation measures, which are built in to the standard activities. Environmental protection plans for each stage of a development (e.g., drilling, production, decommissioning) are usually a condition of approval (e.g., Terra Nova Decision 97.02 (C-NOPB 1997)) and must be addressed in at least a preliminary form in a DA, usually within the EIS.

Regulatory requirements also provide direction on the types of mitigation that can be incorporated into routine activities. For example, the following regulatory tools also enable the effects of drill cuttings and produced water discharge to the environment to be minimized:

- all chemicals which would be discharged into the offshore environment must undergo a screening process and be approved under the Offshore Chemical Selection Guidelines;

- use of low toxicity WBMs and SBMs during drilling;
- compliance with the Offshore Waste Treatment Guidelines (NEB, C-NOPB and C-NSOPB 1996);
- all projects must operate under permits, many of which have specific requirements for environmental compliance monitoring; and
- projects must undertake an environmental effects monitoring program (as discussed in Section 6.4) to provide feedback on potential environmental changes which have occurred since the onset of the development (including drilling).

Mitigation activities that may be incorporated into the routine activities of a project may include (Petro-Canada 1995; SOEP 1997; Husky Oil 2000):

- no blasting during underwater construction;
- recycling drill muds and returning muds to shore when no longer useful;
- treating drill cuttings and produced water (as per the Offshore Waste Treatment Guidelines) prior to discharge and/or re-injecting drill cuttings and produced water;
- treating other discharges such as deck drainage and ballast water (as per the Offshore Waste Treatment Guidelines) prior to discharge;
- having a waste management plan in place;
- having contingency plans in place for accidental events (such as oil spills)
- providing training, maintaining clean-up equipment inventory and practicing prevention (*i.e.,* "zero tolerance") to mitigate against an accidental event (oil spill);
- designing equipment to reduce the amount of fugitive atmospheric emissions;
- releasing stranded birds which may have been attracted to a platform;
- avoiding seabird colonies and concentrations of marine mammals during vessel transport;
- avoiding colonies and repeated overflights of bird concentrations during helicopter transport;
- maintaining steady course and vessel speed when possible;
- flying helicopters at minimum altitude of 600 m whenever possible; and
- removal of subsea equipment at abandonment.

The C-NSOPB has provided direction for mitigation and operating procedures for seismic activity during the exploration phase. In 1998, the C-NSOPB required that the following operating conditions be met to mitigate potential adverse environmental effects (C-NSOPB 1998):

- proponents must "ramp-up" the noise of the airgun array to warn marine mammals and to allow them to take evasive action before being exposed to the full array;
- proponents will avoid undertaking seismic operations in the DFO whale sanctuary on the Roseway Basin, from July through November, to avoid disturbance to the endangered northern right whale;
- proponents will not be permitted to undertake operations in the Gully, throughout the 1998 seismic

season, to allow the DFO and others time to develop a Gully Conservation Strategy;

- scheduling of seismic activities should be addressed, to the fullest extent possible, to minimize potential disturbance of vulnerable ecological resources as identified in the LGL class screening report;
- proponents must ensure, to the fullest extent practical, that oily and other liquid wastes are not discharged from the seismic vessel. Discharges of solid waste or persistent litter will not be permitted. Any spills of oil or other hazardous substances should be reported immediately to the C-NSOPB and the Canadian Coast Guard;
- proponents are encouraged to consult with the fishing industry to mitigate against any potential conflicts at sea with commercial fishing operations;
- to provide effective liaison with fishermen who may be in the vicinity of seismic programs, seismic operators are to include a qualified fisheries liaison observer, who ideally is also experienced in observing marine mammals and seabirds. The observer would meet with appropriate fisheries groups prior to commencing the seismic program, and would be onboard to further reduce the likelihood of conflicts at sea. The Seafood Producers Association of Nova Scotia (SPANS) can be contacted to arrange for a qualified observer. This requirement was to be reviewed after the 1998 season; and
- proponents should be aware of improvements in seismic technology, which may be requested by the C-NSOPB for future seismic exploration programs particularly in, or adjacent to, sensitive areas.

The current status of these mitigations/conditions is not known.

6.3 Environmental Management Systems

Many oil and gas companies (in fact, most industries) have adopted environmental management systems (EMS), which provide a policy driven down from the top leadership in a company (*i.e.,* endorsed by the Chief Executive Officer). An EMS policy (plus the programs and procedures that support it) assists a company to provide due diligence and responsibility in its stewardship of health, safety and the environment. Many EMS comply with the requirements of the ISO 14001 standard "Environmental Management Systems - Specifications with Guidance for Use".

An Environmental Management System (which has as its precursor environmental management plans, which are now components of an EMS) can include the following components (which are often a condition of project approval (C-NOPB 1997)):

- an environmental effects monitoring program (see Section 6.4);
- an environmental compliance plan (Section 6.3);
- a waste management plan (Section 6.3);
- a fishing industry agreements and compensation procedures plan;
- a chemical management plan (Section 6.3);

- phase-specific environmental protection plans; and
- a contingency plan for environmental emergencies (Section 6.3).

These plans are often controlled documents within corporate structure (*i.e.,* numbered documents are provided to specific responsible individuals and updated with clearly identified revisions). Examples within the Canadian oil and gas industry include Total Loss Management (TLM) National Standards (Petro-Canada 1997), and Health, Safety and Environment (HS&E) Loss Control Management Performance Standards (Husky Oil 1998). These systems are discussed as examples only.

The TLM National Standards (Petro-Canada 1997) state that TLM is "a method of efficiently grouping several functional management areas to help protect People, Facilities, Third Parties and the Environment". The National Standards address a wide range of corporate risk management issues, including those relating directly to environmental management. The National Standards include four areas to be managed, supported by six common elements.

The management areas are:

- health and safety and security;
- equipment integrity and reliability;
- contractor management; and
- environmental management.

The supporting common elements are:

- leadership;
- employee competency;
- audits and inspections;
- external relations;
- emergency preparedness; and
- event management.

The HS&E Loss Control Management Performance Standards (Husky Oil 1998 in Husky 2000) states that adherence to the standards will assist in meeting the following objectives (Husky Oil 2000):

- keeping Husky and contractor employees free from harm;
- ensuring that project facilities and operations are run in a manner that demonstrates to Husky employees, neighbours, regulators and the general public Husky's commitment to HS&E stewardship;
- managing the effects of Husky activities on the environment and the liabilities associated with those potential effects;

- managing risk to protect Husky from loss;
- ensuring clear expectations and appropriate consistency in the Husky's Loss Control Management program; and
- facilitating consistent company-wide application of the Husky Loss Control Management program.

6.4 Environmental Effects Monitoring

6.4.1 Program Design and Implementation

Environmental effects monitoring (EEM) has been a condition of project approval for all Atlantic Canada developments, and is conducted as a matter of routine in many other jurisdictions (see, for example, the Hibernia and Terra Nova Decision Reports (C-NOPB 1986; 1990; 1997)). The EEM programs used in Atlantic Canada are based on the design and experience of other jurisdictions, such as the North Sea and Gulf of Mexico. EEM is conducted to:

- test effects predictions made during the assessment process;
- assess the effectiveness of implemented mitigation; assess the status of the marine environment;
- detect changes in the marine environment; and
- provide an early warning of any undesirable change resulting from the effects of a development on the environment.

Prior to conducting an EEM program, a survey is usually conducted to establish a baseline against which future results may be compared. The goal of the design of a baseline program is to provide a foundation upon which to structure and design the future EEM programs. A design report is usually developed for the baseline survey and provided to regulatory agencies for comment (usually via a lead agency and including review and comment from supporting agencies, for example, the C-NOPB/C-NSOPB takes the lead in Atlantic Canada, with DFO and Environment Canada providing comment on the document).

A baseline survey usually covers a wide geographic area and is designed to incorporate as many potential future design changes as possible (e.g., change in glory hole location). It also includes at least one (but preferably two) reference areas. The reference areas should have the same type of substrate and community structures as in the immediate vicinity of the development, but be far enough away to avoid any influence from existing and future developments (usually a minimum of 20 km 'downstream' of the proposed development). Given the study requirements (*i.e.,* equipment), the biological and biophysical (*i.e.,* sediment) surveys are usually conducted separately. It is important that the biological cruise be conducted when the target monitoring species can be easily collected. Future survey cruises should be conducted during the same time period in successive years.

Prior to the onset of an EEM program, the EEM program is built on the baseline design and based on the final project design. Current Atlantic Canada EEMs are based on a radial design using the platform as the centre of the radial. Additional smaller redial components may be incorporated for those developments with more than one discharge point source (e.g., FPSO and drill centres), or the design may try to incorporate the drill centres along a radial arm. The EEM design is then made available to the regulatory agencies and the public (usually transmitted via open houses) for review and comment. Theoretically, the C-NOPB/C-NSOPB provides approval of the EEM design prior to the onset of the EEM program; however, that is not always the case, and an EEM program may proceed without that approval.

EEM is usually conducted during site development (*i.e.,* drilling) and during production, the timing of which is usually set by the regulatory agency. EEM programs are usually conducted annually for the first three years of production (Years One to Three), then regularly at a longer interval as agreed to with the C-NOPB/C-NSOPB (usually Years Five, Seven and Ten of production). There may also be a requirement for a post-production/abandonment EEM program.

6.4.2 Results of Atlantic Canada EEM Programs

At present, no Atlantic Canada EEM reports are publicly available. Results of baseline surveys of some of the programs were presented at a workshop held in 2000 and co-sponsored by the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) and the Bedford Institute of Oceanography. These are summarized here by program (Gordon *et al.* 2000):

- A seven-year mussel study essentially showed that taint and hydrocarbon uptake did occur in mussels at the Cohasset site (a decommissioned site), with the majority of effects limited to within 500 m of the discharges and hydrocarbon levels quickly returned to background when discharges ended (MacNeil and Full in Gordon *et al.* 2000).
- To date, Hibernia’s operational discharges have not resulted in any major or minor effects outside of a predicted 500 m exclusion zone and hydrocarbons in the sediments decrease to background within 1,000 m from the platform (metals remained at baseline values or below their limits of quantitation) (Taylor in Gordon *et al.* 2001).
- The Sable EEM found visible drill cuttings piles within 70 m of the discharge pipe and elevated levels of total petroleum hydrocarbons and barium (a component of drill muds) were short-lived and generally found between 250 and 500 m from the platforms; dispersion or burial appeared to occur with six months. No taint was detected in sensory evaluations (Hurley in Gordon *et al.* 2000).
- Years One and Two EEM surveys were conducted for the Terra Nova EEM program in 200 and 2001, respectively; results are not yet available (Williams and Murdoch in Gordon *et al.* 2001).

It should be noted that the results of the Atlantic Canada EEM programs (which confirmed the effects predictions, which indicated effects would be within 500 m of the platforms) are similar to results from studies in other jurisdictions. For example, a review of environmental effects of exploration activities in Australia found that while “discharge of drill cuttings and associated fluids does have an effect on the character of the benthos and sediments, the effects are limited in extent to 100 to 200 m down current from the discharge point and the effects are not permanent, with recovery of the benthic character occurring within 6 to 12 months after the cessation of drilling" (URS 2001).

6.5 Cumulative Effects

Consideration of cumulative effects of proposed developments has become increasingly important in recent years. Federal legislation in Canada, the US, the UK, and other jurisdictions requires that cumulative effects be assessed prior to projects proceeding. Methods to assess cumulative effects have been developed and it is standard practice to assess cumulative effects of offshore oil and gas developments in Canada and the US, along with the standard project-specific effects.

The assessment of cumulative effects, or those effects that may result from several projects or activities in a defined geographic region over a defined period of time, is current standard practice for projects subject to *CEAA* (Section 16), and/or the British Columbia *Environmental Assessment Act* (Section 22 (j)). Subsection 16(1)(a) of *CEAA* requires that every environmental assessment must consider any cumulative environmental effects that are "*likely to result from the project in combination with other projects or activities that have been or will be carried out.*"

Methodological approaches and guidance have been developed by the Canadian Environmental Assessment Agency (the "CEA Agency"), and include the:

- *Responsible Authority's Guide* (CEA Agency 1994a);
- *Reference Guide for Addressing Cumulative Environmental Effects* (CEA Agency 1994b); and
- *Cumulative Effects Assessment Practitioners Guide* (Hegmann *et al.* 1999)

In conducting environmental assessment, proponents and practitioners must consider the likely cumulative effects of the project being assessed in combination with other projects or activities that have been or will be carried out. The guidance publications recommend a general methodological framework to assess cumulative effects:

- scoping;
- analysis of effects;
- identification of mitigation;
- evaluation of significance; and
- follow-up.

It is also standard practice in the United States to assess cumulative effects of offshore oil and gas projects pursuant to the *National Environmental Policy Act* and the Council on Environmental Quality's (CEQ) implementation regulations. There is provision in the United Kingdom, pursuant to the *Offshore Petroleum Production and Pipe-Lines (Assessment of Environmental Effects) Regulations*, SI No. 360, and in accordance with the UK's Environmental Statement/Pon 15 system, for cumulative effects to be considered in an environmental assessment.

6.5.1 Canadian East Coast Experience

6.5.1.1 Exploration Phase

Class Environmental Assessment for Seismic Exploration

The C-NSOPB conducted a Class Environmental Assessment for Seismic Exploration in the Scotian Shelf (C-NSOPB 1998). The intent of a class screening is to evaluate the potential environmental effects of a group of projects that are not expected to result in significant adverse environmental effects. Seismic exploration is generally transitory and does not introduce chemical contaminants into the marine environment. Therefore, the potential residual effects from seismic operations on the Scotian Shelf were considered to be insignificant provided appropriate mitigation measures are implemented (C-NOSPB 1998). The one caveat is the potential for significant cumulative effects if exploration eventually leads to several development proposals on the Scotian Shelf. The report indicated these potential cumulative effects should be addressed in more detail during the assessment of future development plan applications. The Class Environmental assessment used existing information and the C-NSOPB made the following conclusions (C-NSOPB 1998):

- the potential for adverse cumulative effects to occur, if effects threshold are exceeded, must be recognized;
- the effects thresholds have not been determined;
- cumulative effects are difficult to evaluate due to the speculative nature of offshore petroleum exploration;
- in addition to other documented activities, the C-NSOPB felt that cumulative effects could also result from: long-range atmospheric transport of contaminants, contaminant input from rivers and coastal land-based sources, the effect of fossil fuels on global warming, and growth-inducing potential of the identification of promising petroleum resource;
- authorization requests for future exploration activities must include an overview of potential cumulative effects. Development applications must be prepared to include a thorough evaluation of the potential cumulative effects of the project in question, in conjunction with past, present and reasonably foreseeable projects and stresses to the marine environment;
- the C-NSOPB recommended that a research proposal be developed, with potential funding from the Environmental Studies Research Fund (ESRF) to examine the effects of seismic shooting on larger toothed whales such as sperm and northern bottlenose whales, and on the commercial herring fishery; and
- the C-NSOPB recommended that effects thresholds be developed for important ecological indicators on the Scotian Shelf. Indicators could range from contaminant concentrations in water and

sediments to populations of endangered or threatened cetaceans on the Scotian Shelf.

Generic Environmental Assessment of Exploration Drilling off Nova Scotia

In 2000, the C-NSOPB and C-NOPB commissioned a generic environmental assessment for offshore exploration on the Scotian Shelf and the St. Pierre Bank (LGL 2000). The effects, including cumulative effects, of a typical exploration program (geophysical surveys, exploration drilling, well testing, delineation drilling), in combination with fishing, shipping, the Sable Offshore Energy Project (SOEP), and future projects, were assessed. The study focussed on the following Valued Environmental Components (VECs):

- fish larvae;
- fish and invertebrates;
- fisheries;
- marine mammals;
- marine birds;
- sea turtles; and
- special areas, including
  - fish nursery areas,
  - The Gully,
  - right whale habitat, and
  - Sable Island.

Potential cumulative effects were identified as:

- Noise and Disturbance - The study concluded that the incremental noise of supply vessels and drilling rigs "would not add significantly to existing ambient noise levels in the study area" (LGL 2000). Although noise from activities at several exploration wells would increase the number of site-specific areas exposed to increased noise levels, "…they would not add significantly to the overall noise on a regional level" (LGL 2000). Mitigative measures included the avoidance of seabird colonies, seal haul-out areas and whale sanctuaries by vessels and aircraft.
- Operational Discharges of Oil - The study concluded that operational discharges of oil from exploration activities would be negligible and would not add significantly to the current input of oil from other discharges (e.g., ships, river run-off, atmospheric deposition and natural seeps).
- Disruption of the Benthos - The study concluded that, although drilling operations would cause some disruption of the benthos through smothering with mud and cuttings and through effects of water-based muds to distances of a few hundred metres from the drill site, the small areas that would be affected would result "…in very small increases in the amount of bottom perturbations that already exists" due to trawling or dredging activities of commercial fishing vessels (LGL 2000). The study also concluded that there may be some minor, sub-lethal effects on deep-sea corals, but there would

unlikely be mortality because the drilling mud is well dispersed by the time it reaches the sea floor.

- Garbage and Waste Materials - Garbage and waste materials will not be discharged to the marine environment, and therefore will not contribute to cumulative effects.
- Accidental Spills of Oil - The study examined potential cumulative effects of a blowout. The study concluded that in the unlikely event of a blowout, the effects would be limited to offshore waters, and that among the VECs, birds would be the most likely to be affected, although significant effects to seabird populations would not occur. Other activities currently occurring that result in seabird mortalities include operational discharges from ships, nearshore spills, capture in fishing gear, and hunting.

6.5.1.2 Development Phase

Cumulative effects of the production phase have been assessed for numerous developments and are contained in environmental assessment documents. With the exception of the Hibernia Oilfield EIS, which was completed in 1985, the environmental assessments of offshore oil and gas developments on Canada's East Coast have included consideration of cumulative effects. Cumulative effects have been assessed for: other oil and gas projects (including future projects); oil spills; commercial fishing; commercial shipping; climactic change; exploration activity; and marine bird hunting on: water quality; benthos; fish; fisheries; fish habitat; marine mammals; seabirds; and sea turtles.

The Sable Offshore Energy Project and the Maritimes and Northeast Pipeline Project (M&NP)

A Joint Public Review Panel was struck to review the two projects together (Sable Gas Projects Panel 1997). SOEP evaluated cumulative effects that could result from the project in combination with commercial fisheries, other oil and gas development (*i.e.,* Cohasset-Panuke), vessel traffic, aquaculture facilities (pipeline construction in the near shore area), industrial discharges, other industrial air emissions, and timber harvesting (on-land pipeline construction). Issues raised during the review focussed on the scope of activities that were assessed, with intervenors recommending that future potential developments on the Scotian Shelf be included and assessed. The Panel accepted SOEP's cumulative effects analysis (*i.e.,* not significant cumulative impacts, localized and controllable cumulative impacts), in consideration of the commitment to monitor environmental effects and to apply appropriate mitigations.

The M&NP project is an on-land pipeline and associated facilities for transporting natural gas product from the SOEP. The M&NP EIS assessed cumulative effects for numerous on-land VECs, focussing on: air quality, wildlife habitat, wildlife and freshwater fish. Other projects or activities that were considered included: timber harvesting, mining, roads and agriculture. The Panel accepted M&NP's cumulative effects analysis (*i.e.,* the Project is not likely to result in significant adverse cumulative environmental effects), in consideration of the commitment to monitor environmental effects and to apply appropriate mitigations.

Georges Bank Review Panel Report (NRCan and NSPD 1999)

In 1996, a three-member independent Panel was appointed to conduct a public review of potential environmental and socio-economic effects of exploration and drilling on the Canadian side of the Georges Bank. Public meetings, information sessions, community workshops and hearings were held in 1996, 1997, 1998 and 1999 respectively. An Environmental Impact Statement was not prepared for the hearings or meetings (thus, there was no definition of significance to apply to the participants description of potential "significant effects" that could result from ending the moratorium on Georges Bank). The report notes that, as a result, cumulative impacts were not discussed systematically. Participants included representatives of the fisheries sector, the petroleum industry, environmental groups, government departments and agencies, business organizations and companies, elected officials, scientists, consultants, academics and interested citizens. The cumulative effects resulting from the effects of exploration and drilling over a three to four year period and cumulative effects over a longer time scale were both examined. Different points of view were heard by the Panel, from those expressed by a representative of a petroleum company, who indicated that contaminants from one to three exploratory wells would be rapidly dispersed and would probably not overlap in time or space, to views of Environment Canada, who indicated that migrating seabirds would encounter offshore petroleum installations on Georges Bank, Sable Island Bank, and Grand Bank, with "…each constituting a separate and definite hazard". The report noted that some participants were concerned with other potential cumulative effects that could result from exploration activities in combination with fishing operations, marine traffic and land-based marine pollution. Some participants also noted concern with the potential adverse effects to fish stocks and Northern right whale. Some participants noted concerns with longer-term cumulative effects, including bioaccumulation of contaminants, formation and produced water, transportation of hydrocarbons by tanker or pipeline, greenhouse gas emissions, and natural gas and environmental illness. The Panel commented that "In the absence of any specific project proposal, precise quantification of impacts…would necessarily be theoretical or speculative". However, they continue: "…the review of cumulative impacts from exploration does include the possibility of development and production, and these cumulative effects in total could be much more significant than impacts from the initial stages of seismic and exploration drilling". The Panel concluded that "Cumulative effects of exploration include field development and production, which, should these occur, could have significant impacts on the biota and fisheries of Georges" (Note: "significant impact" is not described or defined in the report.)

The Terra Nova Development Project (Petro-Canada 1996)

The EIS concluded that the cumulative effects of development activities within the proposed project would result in minor (not significant) effects to water quality and benthos, minor (not significant) local effects to marine mammals (negligible effects to populations) due to noise, and negligible effects due to oily water discharges. The report concluded that the effects resulting from routine operations would be neither additive nor cumulative, and that effects resulting from oil spills would not be cumulative. The cumulative effects resulting from shipping associated with the project were assessed to be negligible. Although there is some discussion in the EIS with respect to cumulative effects to fish and the fishery, conclusions regarding the significance of such effects are not presented.

The Terra Nova Environmental Assessment Panel released its Report in August 1997, followed by the C-NOPB's Decision Document (C-NOPB 1997). The Panel acknowledged both the importance and challenges of conducting cumulative effects assessment, and made the following recommendations:

- a workshop be convened by the C-NOPB to examine the potential for cumulative effects associated with offshore petroleum development activities, and to develop approaches to monitor them;
- the C-NOPB identify factors necessary for monitoring cumulative effects, and design a plan for implementing a monitoring program;
- future EIS's be required explicitly to incorporate cumulative effects into consideration; and
- the cumulative effects workshop include a discussion of criteria for determining "significance".

The C-NOPB's Decision Document (C-NOPB 1997) acknowledges the importance and challenges of conducting cumulative effects assessment and accepted the recommendation to convene a Workshop. It also noted that the legislative requirement to include consideration of cumulative effects in any future EIS already exists. In its decision, the C-NOPB attached 23 conditions to Petro-Canada's Development Permit. Condition 23 relates to EEM and states (C-NOPB 1997):

> *(i)* *The Proponent submits its Environmental Effects Monitoring (EEM) program respecting the drilling and production phases of the Terra Nova project prior to commencing drilling operations*
>
> *(ii)* *The Proponent provide, during the design of its environmental effects monitoring program, opportunity for the general public to obtain input into, and review, the design.*

The Cumulative Effects Workshop which the Panel recommended and the C-NOPB accepted, was convened in May 2000.

White Rose Oilfield Development

The EIS assessed cumulative effects of project activities in combination with: other oil and gas projects, oil and gas exploration activities, commercial fishing, marine shipping and hunting activity (of marine birds) on fish and fish habitat, marine birds, marine mammals and sea turtles.

Issues such as discharge of oily drill cuttings, produced water, vessel noise, no fishing zone, the commercial fishery and marine transportation were assessed for fish and fish habitat. It was concluded that no effects or not significant cumulative effects would result to fish and fish habitat from routine operations in combination with other projects and activities. The cumulative effects of the White Rose Project in combination with hunting (seabirds) and the commercial fishery on marine birds was determined to be not significant; the cumulative effects of the White Rose Project in combination with vessel traffic on marine mammals was assessed to be not significant. The EIS indicates that Husky Oil (the Proponent for White Rose) was in consultation with other oil and gas operators on the Grand Banks to develop a regional EEM program.

The Commissioner's Report was released on September 26, 2001. The Report recommended that the C-NOPB and DFO work together to establish a regional/cumulative EEM program.

Strategic Environmental Assessment

The C-NSOPB prepared a Strategic Environmental Assessment (SEA), providing a draft for public comment in October of 2000 (C-NSOPB 2000). This report addresses potential cumulative effects of all phases of petroleum production, including exploration.

Although there are many unknowns, it was acknowledged that increased petroleum activity (also in combination with other users of the offshore) would result in greater stress to the marine environment. It was suggested that cumulative effects of increased activities on the Scotian Shelf and Slope, as well as the lack of baseline information, could be addressed either under initiatives under the *Oceans Act* or under funding sources such as the ESRF. It was recommended that ambient targets and thresholds for evaluating the potential significance of cumulative effects be developed, and these ambient criteria be used to identify trends in the total stress burden on marine ecosystems of the Scotian Shelf and slope.

It was noted that the DFO is planning to develop an integrated management plan for the eastern Scotian Shelf, and is in the early stages of identifying areas which may be considered as candidate marine protected areas.

With respect to the exploration phase, the C-NSOPB has a minimum six-week rule for proponents to communicate with fishers, and the placement of observers on seismic vessels to help minimize gear conflicts.

The SEA Report determined that "…cumulative impacts are a particular concern where they may encroach on identified valued areas, such as the Gully and Sable Island". The Gully Science Review found that available evidence suggested the Gully/Sable Island area is the most important habitat for both cetaceans and pinnipeds on the Scotian Shelf (Harrison and Fenton 1998). Increasing exploration and development in that vicinity, even if it does not directly encroach on Sable Island or the Gully, could have repercussions for the fauna that use the Gully and Sable Island area".

6.5.1.3 Overview of Cumulative Effects Workshop

In response to the Terra Nova Environmental Assessment Panel recommendation on the need to address cumulative effects of offshore oil and gas development, a workshop was held in May 2000 on Cumulative Environmental Effects Assessment and Monitoring on the Grand Banks and Scotian Shelf (Hatch and Griffiths Muecke 2000). Over sixty oil and gas industry, fishing industry, government, academic and non-government organization representatives attended. Several issues pertinent to cumulative effects assessment and monitoring were considered; the main conclusions of the workshop are outlined below.

Acceptable Approaches to Cumulative Effects Assessment and Management in the Offshore

- Long-term financial and human resources need to be dedicated to assess cumulative effects.
- A collaborative approach to monitoring cumulative effects should be established, headed up by DFO, or an independent body funded by government and oil and gas companies.
- A multi-stakeholder group should be organized to monitor cumulative effects.
- Cumulative effects should be managed through:
- Establishing marine protected areas and codes of practice;
- Improving fishing practices;
- Identifying traffic and safety zones; and
- Developing integrated management plans to manage seabed footprint changes.

Likelihood of Cumulative Effects

- Uncertainty should be acknowledged.
- Likelihood of impacts may be reduced through improved technology and regulatory regimes.
- Information from EEM should be integrated into resource management decisions and future impact predictions.

Spatial and Temporal Boundaries

- The appropriate selection of spatial and temporal boundaries is critical to determine cumulative effects.

Factors Necessary for Monitoring Potential Effects

- Cumulative effects monitoring should consider: the benthic environment; fish, eggs, and larvae; seabirds; marine mammals; and fisheries.
- The design of a cumulative EEM program should consider effects resulting from: contaminant loading; habitat change; habitat alienation; habitat fragmentation; and direct mortality.

Scientifically Credible Means of Determining "Significance" of Environmental Effects

- Significance of cumulative effects is difficult to determine.
- There are many species for which thresholds are unknown.
- A better knowledge of the duration and recovery time of cumulative effects is required.

Means by which Potential Cumulative Effects may be Monitored

- A consensus-driven approach was recommended.
- A monitoring program should build on existing knowledge.
- Long term reference stations should be established.
- Clear questions or hypotheses should be established.

The Way Forward

Generally, the workshop participants agreed that regional, cumulative effects monitoring is required on the Grand Banks and Scotian Shelf and that a multi-stakeholder body should be established to guide the development of a regional EEM program. It was also noted that communication is essential among all parties and that a sustained effort is required to move cumulative effects assessment forward on a sustained basis.

The central recommendation from the workshop was:

> *That, as soon as possible, C-NOPB and/or ESRF should write to DFO to a) convey the conclusion of the workshop, and b) request that DFO take the lead in convening one or more follow-up meetings involving representatives from all relevant stakeholder groups to discuss how cumulative effects assessment should be pursued on a regional basis.*

Current Status

To date, a regional effects monitoring program has not been established on the Grand Banks or Scotian Shelf.

6.5.2 American Experience

Cumulative effects have also been assessed by the Minerals Management Service (US Department of the Interior) for offshore oil and gas activities in American waters (Gulf of Mexico, Pacific Region, Alaskan Region, and Atlantic Region) (MMS 1997b; 2000; 2001a; 2001b).

Generally, cumulative effects are assessed for any offshore oil and gas project in US Federal waters; at least one environmental assessment report considers cumulative effects to be a major issue (MMS 2001a). Consistent with the Canadian experience, cumulative effects are assessed for the project under consideration, in combination with other past, present and reasonably foreseeable projects that may occur concurrently in space or time (MMS 2000).

Cumulative effects of oil and gas exploration/development proposals, in combination with other activities such as on-going oil and gas activities, commercial fishing, marine shipping and tankering, coastal development, recreational fishing, and fibre cable installation have been assessed on environmental components such as air quality, water quality, benthic substrate, marine mammals, fish, threatened and endangered species, and protected areas. Several recent cumulative effects assessments for offshore oil and gas exploration/developments in US Federal waters are summarized in Appendix 8.

The MMS of the US Department of the Interior reported results from cumulative effects studies in the Gulf of Mexico Region, Pacific Region, Alaska Region, and Atlantic Region from 1992 to 1994 (MMS 1997). For the most part, the reported studies appear to investigate project-specific and site-specific effects, rather than regional, area-wide effects. However, the results are summarized here for reference. The report concludes that Outer Continental Shelf (OCS) activities (over 850 exploratory wells drilled; over 1,200 development wells drilled; over 1 billion barrels of crude oil and condensate produced; nearly 14 trillion cubic feet produced; approximately 681,000 short tons of salt produced; nearly 5.4 million short tons of sulfur produced; 367 OCS platforms installed; over 2,000 line miles of pipeline installed; 392 platforms removed; less than 7,425 barrels of crude oil and condensate spilled) caused only temporary, localized effects on most of the resources that were studied. The cumulative effects identified in the Gulf of Mexico Region were wetland loss, social effects and economic effects. Local onshore impacts were identified in the Pacific Region and social, cultural and subsistence effects were identified in the Alaska Region and Atlantic Region (MMS 1997). This summary of that report focuses on biophysical effects.

6.5.2.1 Gulf of Mexico Region

OCS Activities – 1992 to 1994

- 850 exploratory wells drilled;
- 1,197 production wells drilled;
- 363 OCS platforms installed;
- 391 OCS platforms removed;
- 2,040 miles of OCS pipeline installed; and
- 77 small OCS spills (1 to 999 barrels) resulted in a total oil spillage of 1,001 barrels and two large pipeline spills (1,000 barrels or more) resulted in a total oil spillage of 6,533 barrels.

Air Quality

Air emissions from routine OCS oil and natural gas operations, including nitrogen oxides, volatile organic compounds, sulfur dioxide, particulate matter and carbon monoxide are routinely monitored. The potential impacts of OCS-related emissions on ozone were also studied. It was found that the contribution of OCS-emission sources was less than 0.002 ppm during modelled exceedances of ozone concentrations in Houston/Galveston and Beaumont/Port Arthur, Texas. The MMS were in consultation with the EPA in 1997 to determine if existing regulatory requirements for OCS emission sources were adequate to prevent adverse effects on ozone non-attainment areas. Studies were also conducted on effects of OCS-emission sources on the Breton National Wildlife Refuge.

Drilling Discharges

A three-phase study was initiated in 1992 to investigate the biological communities, chemical contamination and biochemical responses of resident biota beneath three OCS platforms in the northwestern Gulf of Mexico. The study found:

- the platforms had little effect on the seawater that flowed past them;
- sediment texture was observed to be enriched with sand close to the platform. This sand appeared to be related to cuttings disposal;
- inorganic carbon generally increased near the platforms;
- no significant bioaccumulation of hydrocarbons was observed in invertebrates or in fish livers or stomachs for those organisms residing near the platforms;
- no significant bioaccumulation of metals in invertebrates or fish was associated with proximity to the platform;
- pore water within 100 m of the platform was found to be significantly toxic to test organisms. Toxicity appeared to be related to higher levels of metals;
- the abundance of meiofauna (e.g., copepods and nematodes) was consistently lower near platforms;
- macroinfauna abundance and species numbers (especially polychaetes) were greatest within 100 m of the platforms. The abundance and types of amphipods and foraminifera were lower near platforms;
- few observed effects on megafauna (e.g., crabs, shrimp, fish) could be directly attributed to proximity to platforms or contaminant exposure; and
- no discernible differences in enzyme activities were found in sampled fish.

Oil Spills

There were a total of 77 small and two large (greater than 1,000 barrels) OCS spills reported in the Gulf of Mexico from 1992 to 1994. Neither of the two large oil spills resulted in significant effects. Although one spill contacted shore, the effects were minimal. The other spill dissipated before it contacted land.

Chemosynthetic Communities

Effects to chemosynthtic communities are not significant, as drilling operations are not permitted in areas known to support chemosynthetic communities.

Removal of Structures

The primary issue associated with the removal of platforms is the potential injury to marine animals, particularly sea turtles or dolphins, due to explosives detonation. The enforcement of several mitigation measures has resulted in minimal effects to these animals.

Coastal Wetlands

The effects of constructed canals on coastal wetlands were studied; results varied from no impact to "diminished habitat function".

The effects of two separately occurring oil spills on marshes in Louisiana were monitored. The effects of a 300 barrel spill of crude oil in 1985 indicated that:

- a relatively low dosage of crude oil spilled into a coastal brackish marsh can have considerable negative short-term impact on marsh vegetation;
- vegetation in the study area appeared to fully recover within five years after the spill;
- the health of the recolonizing vegetation in oiled plots was found not to be significantly different than that measured in control plots;
- although the spill had a significant short-term impact on the marsh vegetation, analysis revealed that land loss rates in the oil-impacted marsh were consistent with other periods in the past; and
- in many cases, sediment addition, followed by planting or natural colonization, may greatly improve the long-term vegetative recovery success of oil-impacted marshes.

A 2,000-barrel spill occurred in 1992 during Hurricane Andrew. In this instance, natural processes were relied upon for recovery because bringing in additional clean-up equipment would have caused more damage to the marsh. Observers noted in overflights of the area in 1997 that "the marshes appeared healthy and that there were no long-term effects from the oil spill".

Studies were also conducted on the disposal of Normally Occurring Radioactive Material and marine debris on beaches.

6.5.2.2 Pacific Region

OCS Activities 1992-1994

- 50 development wells drilled;
- two production platforms brought online;
- one OCS structure removed; and
- 172 barrels of OCS crude oil and condensate spilled.

Air Quality

Air emissions from routine OCS oil and natural gas operations, including nitrogen oxides, volatile organic compounds, sulfur dioxide, particulate matter and carbon monoxide are routinely monitored. Air quality monitoring studies in the 1980's indicated that OCS emission sources contribute to ambient ozone levels in Santa Barbara and Ventura Counties. OCS emissions were compared to emissions in adjacent onshore jurisdictions; the OCS emissions were equal to approximately 8 and 2 percent, respectively, of the combined N0x and VOC emissions from Santa Barabara and Ventura Counties. They were equal to approximately 1 and 0.2 percent, respectively, of the total NO_X and VOC emissions from the South Coast Air Quality Management District. Pacific Region OCS operators installed various types of pollution control technologies and emission reduction measures to comply with new regulatory standards in the early 1990s.

Oil Spills

There were a total of 92 OCS spills reported in the Pacific Region from 1992 to 1994, including three that were greater than 1 barrel. There were no reports of adverse impacts from these spills, and no reports of oil-contacted marine animals (e.g., mammals, birds).

Drilling Discharges

A three-phase study was initiated in the 1980s to investigate the long-term cumulative effect of offshore drilling and production activities on the marine environment. In summary the study found:

- barium concentrations in bottom sediments increased up to 40 percent during periods of drilling;
- barium concentrations in suspended particulates increased up to 300 percent during periods of drilling;
- these increases were attributed to contributions of barite associated with drilling muds;
- over time, the levels of barium decreased to background levels in suspended particulates;
- over time, the levels of barium in bottom sediments decreased to slightly elevated over background levels due to the presence of residual barite particles.;

- decreased abundances for 4 of the 22 taxa surveyed were recorded (timing was not indicated). The study concluded the decreases were likely due to disruption of feeding, respiration and/or postlarval survivorship due to burial rather than responses to toxicity; and
- Phase III results (1991-1992) indicated:
  - there were no obvious residual effects on hard-bottom communities,
  - concentrations of chemical contaminants were at or near background concentrations for all those analyzed with the exception of a small residual amount of barium,
  - there were no residual impacts on the four taxa that had decreased abundances during Phase II, and
  - surface-generated waves did not cause re-suspension at deeper bottom depths (e.g., 138 m), but that transport and re-suspension is greater at shallower depths (e.g., 105 to 119 m).

Commercial Fisheries

OCS operators are required to conduct activities in a manner that would avoid undue interference with commercial fishing activities. In the event of fishing gear/vessel damage or loss, compensation can be filed through the Fisherman's Contingency Fund.

Observations which may have some relevance for OCS-activities included:

- there were distinct differences in the fish assemblages between a surveyed platform and near-by natural reefs. Mid-water rockfish were dominant at the platform, whereas bottom-associated species were not common;
- platform mariculture of mussels, oysters, scallops, and clams in the Santa Barbara channel has been successful; and
- exclusion zones (approximately 3 mi^2) established during the installation or removal of structures do not substantially increase the long-term or cumulative impacts on commercial fisheries. Communications of plans with local fishers and relevant agencies, and implementation of mitigation measures are conditions of approval.

An overview of the expansion of the Santa Ynez Unit was also conducted. A multi-stakeholder Offshore Oil and Gas Energy Resources Study was conducted to, in part, address the potential onshore effects of offshore oil and gas development.

6.5.2.3 Alaska Region

OCS Activities 1992-1994

- 20 geological and geophysical exploration permits issued; and
- four exploratory wells drilled.

Water Quality

Up to 12 oil and gas platforms had been discharging drilling muds, cuttings, formation waters and specialty chemicals (e.g., biocides) in Cook Inlet over a period of three decades. In response to expressed concerns, the MMS conducted a joint study of Cook Inlet with the University of Alaska to determine:

- the presence of hydrocarbons and trace metal contaminants in the water;
- the accumulation of contaminants in the sediment; and
- the effects of contamination levels on sensitive animal life stages.

Sampling sites were chosen in fine-grained bottom sediment bays, in the vicinity of production platforms in upper Cook Inlet, and in bays near processing and transportation facilities in northern lower Cook Inlet.

The physical chemical and bioassay results of the Cook Inlet Water Quality Study "…showed that Cook Inlet had very low environmental concentrations of hydrocarbons and that the sediments and water were generally free from toxic components. The results also showed no immediate evidence of heavy metal pollution in Cook Inlet".

Bowhead Whales

In the US, protection of the bowhead whale is required under the *Marine Mammal Protection Act* (1972) and the *Endangered Species Act* (1973). Site-specific effects of exploratory activities on bowhead whales must be monitored by industry for OCS leases in the Beaufort Sea Planning Area:

> "The lessee shall conduct a site-specific monitoring program during exploratory drilling activities to determine when bowhead whales are present in the vicinity of lease operations and the extent of behavioural effects on bowhead whales due to these activities."

MMS reviews the information an on annual basis with NMFS and the State of Alaska to determine whether existing mitigating measures adequately protect the whales from serious, irreparable, or immediate harm from oil exploration activities.

Broad-scale effects on the distribution, abundance, and behaviour of bowhead whales in the Beaufort sea are monitored each fall migration period. The surveys provide real-time data on the progress of migration and are used to limit OCS exploratory activities.

Aerial surveys in 1992, 1993, and 1994 indicated that bowhead whale fall migrations exhibited patterns found in previous years. A site-specific monitoring program at the Kuvlum area was also conducted in 1992 and 1993. Results from the 1992 program indicated that bowhead whales migrated north of an exploratory well in the Kuvlum #1 monitoring area; although ice conditions may have influenced the shift, industrial activity could not be eliminated as a source for the observed shift in distribution of bowhead whales. The 1993 program results indicated that bowhead whale distribution in the same area was within previously recorded fall migration distributions. The cause(s) of this local and temporary avoidance of some OCS exploration activities was not clear, and could have resulted from heavy ice conditions or industrial activity. The MMS "…found no evidence of serious, irreparable, or immediate harm to the bowhead whales from OCS-related activities during 1992-1994".

8.0 CONCLUSIONS

This report has focused on the potential environmental impacts and socio-economic benefits that could result from the exploration and development of oil and gas reservoirs in the offshore and near onshore areas of British Columbia. The evidence, from a relatively extensive review of conditions off British Columbia in comparison with other oil and gas areas worldwide and the latest engineering technology that applies to development, indicates that there are no unique fatal flaw issues that would rule out exploration and development activities.

While earthquake risks are higher than in most, but not all, oil and gas areas, technology exists to minimize the risks in accordance with generally accepted principals of sociatal risk factors. More extensive investigations would be required than in many locations to identify hazard areas. Design technologies are available to provide security to facilities during major earthquake and storm events. The cost of facilities required to protect the environment may make the economic justification of exploration and development questionable, depending on the reserves available at a given location. Regardless, state-of-the-art designs can be implemented to ensure satisfactory risk factors related to potential environmental damage and human safety.

Environmental Impact Assessments conducted for offshore oil and gas operationsin Atlantic Canada and other jurisdictions have identified a number of potential environmental effects of offshore oil and gas development and operations on the biological environment. Where effects were identified, strategies for mitigating these effects, such as implementation of Environmental Management Systems or modification of engineering technologies used to undertake specific activities, have been able to reduce the potential environmental effects to levels considered by regulatory agencies as not significant. In addition, cumulative effects assessments have concluded that the effects resulting from routine operations, when managed in accordance with regulations and best managemnet practives, would be neither additive nor cumulative.

One of the important issues to be addressed by Government in the regulation of oil and gas developments offshore will be the degree to which regulations are prescriptive. The eastern Canadian offshore regulations are heavily prescriptive which can place a significant cost burden on potential offshore activities. With the advances in the technology of offshore investigations, drilling and production, there is significant opportunity to use a results oriented, review and approval process to ensure the highest economic benefit while ensuring that the potential for environmental and safety risks are adequately controlled.

In conclusion, the study has found that there are no specific design, geohazard or environmental issues that would preclude the development of the offshore oil and gas reservoirs of British Columbia. However, the economic viability of a specific reservoir may be adversely impacted by the costs associated with mitigating the geohazard and environmental risks.

9.0 CLOSURE

This report entitled *British Columbia Offshore Oil and Gas Technology Update* is an update of the 1998 AGRA Earth and Environmental Limited report *Review of Offshore Development Technologies* prepared for the British Columbia Information, Science and Technology Agency. This update report is a component of the provincial government's review of the offshore oil and gas moratorium and is an extension of the process that includes the 1986 *Offshore Hydrocarbon Exploration, a Report and Recommendations of the West Coast Offshore Exploration Environmental Assessment Panel* and the 1998 AGRA report. Jacques Whitford Environment Limited has prepared this document as an unbiased update of offshore oil and gas engineering, environmental and socio-economic factors, and state-of-the-art technologies.

This report has been prepared for the sole benefit of the British Columbia Ministry of Energy and Mines (MEM). Preparation of the text has been completed by Jacques Whitford Environment Limited (Vancouver, BC and St. John's, NF) in association with Sea Science Inc. (Vancouver, BC) and Gardner Pinfold Consulting Economists Limited (Halifax, NS). Much of this information contained herein has been obtained from the literature, references and other individuals. These have been referenced, where appropriate. The authors thank the various individuals and organizations who have provided comments and data for inclusion in this report. Special thanks is extended to Tera Remote Sensing Inc. (Sidney, BC), Fisheries and Oceans Canada, The Geological Survey of Canada and Gordon Hanson and Associates Inc. (Salt Spring Island) for their input. The authors have utilized their collective experience in the applicable technologies, environmental issues and the offshore oil and gas industry in the preparation of this report.

Respectfully Submitted,

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APPENDIX 1

SUMMARY OF DFO'S HADD COMPENSATION PROCESS

Any project that is referred to DFO is reviewed to determine if there is likely to be a HADD to productive fish habitat as defined under Section 35 of the *Fisheries Act*. DFO have a hierarchy of preferred options to avoid a HADD. These are, in order of preference:

- **relocation** or physically moving a project, or part of a project, to eliminate adverse impacts on fish habitat;
- **redesign** of a project so that it no longer has negative impacts on fish habitat;
- **mitigation** of impacts in cases where relocation and redesign are not possible; or
- **compensation**, which involves replacing damaged habitat with newly created habitat or improving the productive capacity of some other natural habitat.

Compensation is DFO's least preferred option and as such, should only be considered when relocation and redesign prove impractical and where mitigation measures fail to avoid a HADD.

Once a HADD is determined to occur, and it cannot be avoided by the first three options above, the federal Fisheries Minister, under Section 35(2) of the *Fisheries Act*, must authorize the HADD or the project cannot proceed. The authorization may be granted on the condition that losses to habitat caused by the project must be balanced by gains elsewhere. This requirement stems from DFO's Policy for the Management of Fish Habitat, which states that there shall be no net loss of fisheries habitat. A quantification of the potential HADD, proposed compensation, a schedule and any required follow-up will be detailed in a Compensation Plan developed by the Proponent. Based on this plan, a legally binding Compensation Agreement will be entered into by the Proponent and DFO and the agreement will be appended to the authorization granted by the Minister. The requirement for an authorization is a *CEAA* trigger that initiates a federal environmental review.

The amount of HADD is usually quantified based on known project activities that have a defined 'footprint' that will disrupt, damage or alter fish habitat (i.e., seabed). This can include construction of glory holes, installation of subsea infrastructure, installation of pipelines, etc. The total surface 'footprint' area that is affected by project activities is calculated. To complete the environmental review, DFO requires an acceptable habitat compensation strategy to be developed. The habitat compensation strategy provides alternatives that could be used to compensate for lost habitat.

Alternatives that would provide habitat compensation should be considered in terms of a hierarchy of preferred compensation options:

- 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; or
- increase the productive capacity of existing habitat for a different stock or a different species of

fish either on or off site.

Compensation may not be an option for particularly valuable habitat.

In some cases, more than one alternative may be used in a single project to protect and maintain habitat capacity to produce fish. Once agreement has been reached for a habitat compensation strategy, the Proponent than prepares a Habitat Compensation Plan, which provides specific information on the selected strategy (and transmits that information to the public) and details how the strategy will be implemented and monitored.

Examples of marine habitat compensation plans in Atlantic Canada include the:

- construction of a reef to provide lobster habitat in the vicinity of a wharf constructed for the Newfoundland Transshipment Terminal (which provides on-land storage for crude from the offshore platforms prior to second-leg tanker transport to markets); and
- creation of nearshore habitat for Iceland scallops to compensate for offshore Iceland scallop habitat lost due to the excavation of glory holes and burial of a seabed pipeline for the Terra Nova development (offshore Newfoundland).

APPENDIX 2

FIRST NATIONS POSITIONS ON THE OFFSHORE OIL AND GAS MORATORIUMS

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Press Release

Tsimshian and Haida Statement on the Moratorium on North Coast Oil and Gas Exploration

May 14, 2001

The Tsimshian Nation and the Haida Nation continue to support the Moratorium on Offshore Oil and Gas Exploration. The Tsimshian and Haida have examined the issues and determined that the reasons cited for initiating the Moratorium have not changed. "The petroleum interests that are being promoted are within the territorial seas of our people, says Deborah Jeffrey, President of the Tsimshian Tribal Council. "Our culture and identities are integrally tied to our land and seas, including the marine resources."

The cultures of Northwest Coast peoples are derived from their relationship with their lands. The marine environment is amongst the richest on the planet while the coastal rainforests attract visitors from around the world. "The risk of harm from an accidental spill or from allowable discharge is not acceptable and they expect us bear the risk, says Guujaw, President of the Council of Haida Nation. "We intend to pass on a life and culture to the following generations which includes fish and birds."

The position of the Tsimshian and the Haida is consistent with the position of the federal government. The Environment Minister David Anderson stated previously in the media dated August 9, 2000: "I am not going to in any way support lifting of the moratorium until it's clearly shown that the reasons for having it in the first place are no longer valid." He stated interested parties would have to satisfy concerns about the environment, the fishery, earthquakes and aboriginal involvement in any proposal.

Deborah Jeffrey, President of the Tsimshian Nation and Guujaaw, President of the Haida Nation are united in their statement to the federal and provincial governments, "The Moratorium on Offshore Oil and Gas Explorations must remain in place."

For further information:

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Tsimshian Tribal Council
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Guujaaw, President
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SPEAKING NOTES - GARRY REECE
OIL AND GAS CONFERENCE
OCTOBER 2, 2001

Thank you for inviting me to speak at this important conference. These are significant issues before us, and I appreciate the recognition that First Nation involvement is essential to any suggestion that development can proceed under any conditions.

I'd like to start by referring you to the official joint position of the Tsimshian Tribal Council and the Haida Nation, which opposes oil and gas exploration and development in our waters at this time. We are full members of the Tsimshian Tribal Council, but I should note that I represent only the Lax Kw'alaams Band at this meeting, and my comments come only from myself as Chief of that Band.

THE LAX KW'ALAAMS BAND.

As the elected Chief of the Lax Kw'alaams Band, let me tell you more about our Band for those of you who are not familiar with us:

- ❑ we are one of BC's largest bands
- ❑ with approximately 2,700 members; 1300 live in the Village of Lax Kw'alaams, at Port Simpson, north of Prince Rupert, which is accessible only by ferry and air service
- ❑ the Band has jurisdiction over 72 reserves totalling some 11,800 hectares of land.
- ❑ separately governed (an elected council and Hereditary system) but also a member of the Tsimshian Nation; full participants in the Tsimshian Tribal Council
- ❑ our membership consists of nine of the fourteen tribes of the Tsimshian Nation
- ❑ have occupied the north coast since time immemorial, there is evidence of 5,000 years of occupation in the Prince Rupert area
- ❑ The Lax Kw'alaams are in Treaty process, as a member of the Tsimshian Tribal Council, but are not yet at the Approval in Principle stage. (Things, as you know, are going slowly, and the current approach of the Lax Kw'alaams Band is not to stake our future on this process. We intend to move forward through economic development initiatives to become completely self-sufficient)

The Lax Kw'alaams Band have long been participants in the modern economy. The Band has business interests:

- ❑ in commercial fishing
- ❑ participated extensively in the commercial salmon, halibut, herring and other fisheries since the commercial fishery started,
- ❑ set up Lax Kw'alaams Marine Industries which operated a cannery ever since the 1970's
- ❑ participated in joint ventures with fish processing companies, (currently one is active)

- ❑ and logging:
- ❑ set up the Lax Kw'alaams Development Corporation which engaged in logging on reserve through the 1980's and 1990's
- ❑ set up and operates Tsimskow Resources Ltd. which does contract logging and silviculture sub-contracting, and a non-replaceable 10 yr Forest Licence with a significant volume.

- ❑ and we're also no stranger to the Oil and Gas industry, and not adverse to doing business: In the 1980s the Band entered into a comprehensive agreement with Dome Petroleum regarding the development of a liquid natural gas plant, which was ground-breaking at the time, and one that showed the industry that reasonably progressive relationships are possible.

Reliance on the Sea

For us the sea is not an "industry", it is our life. Our people have traditionally relied on the ocean for a very wide variety of resources – from salmon, herring, groundfish, to abalone, sea urchin, kelp etc.

We fish commercially, it is still our largest source of employment, it is still the basis of our culture. Its value cannot be measured in money.

Each of these activities, all of which have their own seasons, and each of which have traditional practices, modern methods and commercial implications, are potentially impacted by both the possibilities of lower-level chronic impacts, and by the possibility of a catastrophic spill.

Consideration of the Full Risks to First Nations

I am not a scientist, but I do know something of the wide variety of possible negative effects of the proposed developments. I will leave it to others to talk of these in detail. But issues for us that would suggest that oil and gas development could be unacceptable or possibly devastating to us include:

- ❑ the sensitivity of the Coastal environment in general
- ❑ the salmon and other commercial fisheries
- ❑ Seismic exploration and noise effects on the marine environment
- ❑ Groundfish and other less mobile species
- ❑ General toxic effects on wildlife, sea mammals like otters and seals
- ❑ the Big Spill (even low risk is unacceptable if impacts are devastating)
- ❑ The negative effects on other economic development alternatives – eg. tourism, alternative fisheries, acquaculture etc.

I note however, that for us, this issue is not limited to environmental or technical matters – primarily perhaps this is a social issue. From a whole range of possibilities, our culture is put at risk, not only from any disaster, or environmental impacts, but also by the possible changes that large industrial activity will bring to us.

Also, please do not suggest that the risk of exploration are lower than that of production. That may indeed be true, but we know this: if exploration produces significant developable reserves, they will be developed. The pressures for development will be huge. Why look for oil and gas unless you intend to produce it.

The Benefits – How much would really come to First Nations?

Any analysis that was intended to justify such risks, would, it is fair for any government to say, have to be justified by a clear cost-benefit analysis, and one that ensured that the provable and certain benefits clearly outweighed the risks – the benefits to us, and the risks to us.

We are told there are very significant economic benefits to be obtained from oil and gas development, and these will be shared fairly with First Nations. We are told that the risks can be mitigated, and that science and technology have evolved to the point where there is no risk.

We have one thing to say to this: "PROVE IT".

Promises and good intentions will never be enough to put our way of life and our lands at risk.

Do you wonder that First Nations should be suspicious?

- o If you look at the history of the crisis in our fisheries and the so-called scientific management of salmon and other species;
- o If you look at forestry and mining, and how few benefits have gone to First Nations;
- o If you look at the general process of "consultation" and how little difference it has made to most decisions;

the wonder is not that First Nations would be cynical, the wonder is that First Nations representatives like myself might still have an open mind, might still be willing to discuss these issues.

If we look to the experience in B.C. with forestry, with mining, with the fishery; even if we look to Northeastern B.C. and the oil and gas there, we do not see an overwhelming history of fairness in the distribution of resource opportunities, opportunities that once belonged exclusively to our nations.

First Nations do not want to have a few of their members employed in your operations. Yes, we need employment, but such employment alone is insufficient, and can even be disruptive of our culture and communities. First Nations today want an ownership stake in the businesses and opportunities that arise, we want revenue sharing, and an effective role in decision making. We want to be full and active participants if we would ever accept the very substantial risks to our lands and resources and way of life that this activity suggests.

Do not make the mistake of assuming that First Nations have a knee-jerk and uninformed opposition to oil and gas exploration. Yes, we have an immediate and fundamental realization of the potential risks. But Band governments like ours also have the capacity to make sophisticated decisions, based on science and business. We have the capacity to make decisions with an open mind (but with open eyes as well, and full awareness of past lessons). But, where significant risks exist that will primarily be borne by us, do not expect us anymore to make these decisions without a full assessment of these risks.

Need for First Nations-led Investigations
And perhaps more importantly, do not assume that we will be satisfied by the investigations controlled by others, whether it is government sponsored Environmental Assessment Panels, or inquiries, or by company-led scientific consultant reports, or particularly by the current proposed provincial government process.

Those who will bear the risks should make the assessment.

First Nations have legal and moral rights in the coastal areas on which exploration would occur. We are the major users of marine resources. Outside of the cities, we are the primary inhabitants of most of the coastal areas. We are the ones who will suffer the risks. We do not intend to allow this exploration or development to proceed unless it has our full consent.

And I cannot contemplate that we would ever give our consent until we had conducted our own investigation of all the facts in a manner we could trust.

The inadequacy of Consultation
Do not make the mistake that governments and other industries have made in thinking that simple "consultation" will satisfy our concerns. 'Consultation' has become a dirty word to many First Nations because it usually occurs after industry has formulated its plans, after it has spent years in planning and talking to government, after decisions in principle have been made and, generally, far too late to have any honesty or integrity. Such consultation is designed to soothe First Nations, to convince us that real risks are not real, that real harms are not harmful, and to buy our acceptance of the inevitable for bits and pieces and pennies on the dollar. First Nations have come to realize that no matter how friendly and decent the bureaucrat who comes to consult, no matter how lengthy the process, there is little value in such consultation.

In the past, First Nations received 'Trinkets and Beads' for valuable goods or lands – that is no longer something which we will accept.

Need for Dialogue Now
We are told that the Canadian Association of Petroleum Producers and companies like PetroCanada and Shell have confirmed that they will not be involved in activity off our coasts until land claim issues are settled. If they are sincere, we applaud them. Of course, if they are honest in waiting for Treaties, at the rate that process is going, we may all be waiting a very long time.

But even then, I caution industry that they should not, must not, wait until that time, and then expect to proceed without First Nations involvement. It is very much in the interest of everyone to have honest dialogue now, if you ever wish to proceed in good faith.

If there is one piece of advice I can give industry (and government), it is this: if you want to do business in First Nation lands, on our coasts, in our seas – We must be involved and we must be involved at the front end. You must start working with us BEFORE you complete the planning process, before or at least in parallel with your consultations with other governments.

You need to start working with First Nations now, you need to spend as much money and effort understanding us and our use of the sea and our lands, as you do understanding the geology and the environmental and technical challenges. You need to work with us to understand the very real risks. You need to ensure that the benefits you propose are real and substantial, and are real and substantial to the First Nation communities who inhabit the area. And most importantly, you need to respect us, and respect our rights, and respect our decision making processes. Then, perhaps, we can do business in a way that works for you, and for us.

Thank you.

APPENDIX 3

SUMMARY OF CUMULATIVE EFFECTS ASSESSMENT FOR

OFFSHORE OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITIES IN US FEDERAL WATERS

Environmental Component	Other Projects and Activities	Conclusions
Source Document/EIS: OCS Environmental Assessment. Extended-Reach Exploratory Drilling Project		
Air Quality	• On-going oil and gas activities. • Marine Shipping and Tankering	Insignificant increase to overall cumulative air quality No cumulative impacts expected to regional air quality
Marine Water Quality	• On-going oil and gas activities • Intermittent River Run-off	No incremental additive effect
Fish Resources	• On-going oil and gas activities • Dredging • Discharge of Dredged material • Water-intake structures • Aquaculture • Wastewater Discharge • Oil and Hazardous Waste Spills • Coastal Development • Agricultural Run-off • Commercial fishing • Recreational fishing	Impacts from the proposed project are not expected to add measureably to cumulative impacts
Protected Areas		Refer to other sections
Source Document/EIS: Delineation Drilling Activities in Federal Waters Offshore Santa Barbara County, California: Draft Environmental Impact Statement (2002-2006 Timeframe)		
Air Quality	• On-going and proposed oil and gas activities • Natural petroleum seeps • Marine shipping and tankering	The potential is low for incremental emissions to add to cumulative impacts to air quality (low = insignificant)
Water Quality	• On-going and proposed oil and gas activities • Municipal and industrial wastewater discharges • River run-off • Oil Spills	The discharge of drilling muds and cuttings may overlap in space and time with other projects or activities Oil spills may result in short-term moderate (significant) impacts, and long-term low (insignificant) impacts Incremental impacts from the proposed project are low (insignificant)
Seafloor Resources	• On-going and proposed oil and gas activities • Commercial fishing • Fiber cable installation • Sediment and contaminant	Overall impacts to high relief hard bottom habitat are high from all sources, particularly commercial fishing activities. Irreversible habitat alteration resulting from the proposed projects could occur from anchoring activities. Overall impacts to soft bottom resources is low

Environmental Component	Other Projects and Activities	Conclusions
Fish Resources	• On-going and proposed oil and gas activities • Tankering • Military operations • Dredging • Discharge of dredged material • Aquaculture • Coastal development • Agricultural runoff • Commercial fishing	The proposed project will add a negligible increment to the overall cumulative effects on fish resources
Marine mammals	• On-going and proposed oil and gas activities • Oil spills • Military Activities • Commercial Fisheries • Other Anthropogenic Activities (e.g., vessel strikes, marine pollution) • Non-anthropogenic (e.g., disease)	The incremental contribution of the proposed project on cumulative effects is expected to be negligible to low (insignificant)
Threatened and Endangered Species	• On-going and proposed oil and gas activities • Oil spills • Military Activities • Commercial Fisheries • Other Anthropogenic Activities (e.g., vessel strikes, marine pollution) • Non-anthropogenic (e.g., disease)	The incremental contribution of the proposed project on cumulative effects is expected to be negligible to low (insignificant) Negligible to low (insignificant) impacts may occur to blue, fin, and humpback whales from the proposed project. No impacts are expected to sei, right or sperm whales, Steller sea lions, Guadalupe fur seal, or southern sea otters Negligible impacts to sea turtles as a result of the proposed project is expected.
Protected Areas		No impact is expected
Cultural resources		No impact is expected
Source Document/EIS: Delineation Drilling Activities in Federal Waters Offshore Santa Barbara County, California: Draft Environmental Impact Statement (2002-2030 Timeframe)		
Air Quality	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Marine shipping and tankering	Level of effect is speculative and uncertain A more comprehensive review is required as oil and gas developments progress
	• Oil Spills	Localized, insignificant
Water Quality	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • River input • Sewage Treatment plant Discharge	Low Impact

Environmental Component	Other Projects and Activities	Conclusions
Rocky and Sandy Beach Habitat	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Storm Events • Warm water trends • Natural seeps • Public use	Moderate to high impacts (significant) in Southern California Low to moderate (insignificant to significant) impact to the north
	• Oil Spills	Low to High impact, depending on location and size of spill
Seafloor Resource	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Trawling • Fibre optic cable installation	Low to moderate impacts, depending on whether hard bottom habitat is affected
Kelp Beds	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Warm water trends • Commercial fishing • Vessel traffic • Discharges	Incremental impact of oil and gas development is low
Fish resources	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Commercial fishing • Water Pollution • Habitat degradation	Cumulative impacts to fish resources as a result of oil and gas development are expected to be moderate (significant)
	• Oil spill	The incremental increase in a risk of an oil spill represents a measureable overall cumulative oil spill risk
Marine and Coastal Birds	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Helicopter traffic • Climate events • Pollution • Habitat Loss • Predators • Commercial fishing • Human disturbance	Routine operations of oil and gas development will not contribute to cumulative effects on birds
	• Oil Spills	Moderate to high impact

Environmental Component	Other Projects and Activities	Conclusions
Threatened or endangered species	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Storm Events • Warm water trends • Trawling • Fibre optic cable installation • Commercial fishing • Helicopter traffic • Vessel traffic • Discharges • Natural seeps • Public use	Cumulative impacts from routine oil and gas activities to threatened and endangered marine mammals are expected to be low. Most activities from routine oil and gas activities would not contribute to cumulative effects to threatened and endangered bird species; oil spills and disturbance from helicopter flights range from low to high. Cumulative impacts from routine oil and gas activities to threatened and endangered sea turtles are expected to be negligible. Cumulative impacts from routine oil and gas activities to threatened and endangered amphibians are expected to be negligible Cumulative impacts from routine oil and gas activities to threatened and endangered fish species are expected to be low Most activities from routine oil and gas activities would not contribute to cumulative effects to threatened and endangered plant species; oil spills and construction of onshore facilities range from low to high.
	• Oil Spills	The cumulative impact of an oil spill to threatened or endangered species ranges from low to high, depending on the size, location, timing, and duration of the spill.
Marine Mammals	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Commercial fishing – incidental take • Ship strikes • Pollution • Shipping (Noise) • Military Activities (noise)	Cumulative impacts from routine oil and gas activities are expected to be low
	• Oil spills	Negligible to high, depending the location,, size and duration of the oil spill

Environmental Component	Other Projects and Activities	Conclusions
Estuarine and Wetland Habitats	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Storm Events • Warm water trends • Trawling • Fibre optic cable installation • Commercial fishing • Helicopter traffic • Vessel traffic • Discharges • Natural seeps • Public use • Commercial and residential development	Cumulative impact of oil and gas activities is low Overall cumulative effects from all activities ranges from low to high
Onshore Biological Resources	• Future oil and gas developments (including construction, pipeline installation, and decommissioning) • Storm Events • Warm water trends • Fibre optic cable installation • Helicopter traffic • Discharges • Public use	Cumulative effects from all activities is low to moderate.
Source Document/EIS: Liberty Development and Production Plan – Volume 1: Draft Environmental Impact Statement		
Endangered Species (Bowhead whales, Eiders, Other species)	• On-going oil and gas development activities • Transporting oil through the Trans-Alaska pipeline • Tankering from Valdez • Vessel traffic • Subsistence hunting	The incremental contribution of the Project to cumulative effects is likely to be quite small (not significant) Some bowhead whales may temporarily avoid noise-producing activities
	• Oil spills	A large offshore oil spill could increase adverse cumulative effects to potentially significant population levels
Seals and Polar Bears	• On-going oil and gas development activities • Transporting oil through the Trans-Alaska pipeline • Tankering from Valdez • Sport harvest of Wildlife • Commercial fishing • Subsistence hunting • Habitat alteration	The incremental contribution of the Project to cumulative effects is likely to be quite small (not significant) The Project should only briefly and locally disturb or displace a few seals or polar bears

Environmental Component	Other Projects and Activities	Conclusions
Marine and Coastal Birds	• On-going oil and gas development activities • Transporting oil through the Trans-Alaska pipeline • Tankering from Valdez • Sport harvest of Wildlife • Commercial fishing • Subsistence hunting	The incremental contribution of the Project to cumulative effects is likely to be quite small (not significant) Collisions with structures may occur, but losses are expected to be low
	• Oil Spills	Significant effects could occur to some populations, with particular note to the long-tailed duck and common eider
Terrestrial Mammals	• On-going oil and gas development activities • Transporting oil through the Trans-Alaska pipeline • Tankering from Valdez • Sport harvest of Wildlife • Commercial fishing • Subsistence hunting • Habitat alteration	The incremental contribution of the Project to cumulative effects is likely to be quite small (not significant) Some caribou may be displaced (represents less than 1% of the local short-term disturbance of caribou) The Project should only briefly and locally disturb or displace a few muskoxen and grizzly bears
Lower trophic-level Organisms	• On-going oil and gas development activities	The incremental contribution of the Project to cumulative effects is likely to not be measureable (not significant)
Fishes and Essential Fish Habitat	• On-going oil and gas development activities	The incremental contribution of the Project to cumulative effects is likely to not be measureable (not significant)
	• Oil Spills	The incremental contribution of the Project to cumulative effects is likely to not be measureable on fish populations (not significant)
Vegetation-Wetland Habitats	• On-going oil and gas development activities • Oil Spills (minor issue)	The incremental contribution of the Project to cumulative effects is likely to be less than 1% of the cumulative disturbance effects (not significant)
Archaeological resources	• On-going oil and gas development activities	The incremental contribution of the Project to cumulative effects is likely to be minimal (not significant)
Water Quality	• On-going oil and gas development activities	Sediment effects are expected to be short term, having the greatest impact in the immediate vicinity of the activity Regional long-term, degradation of water quality to levels above regulated criteria due to hydrocarbon contamination is very unlikely
	• Oil spills	A large spill (greater than 500 barrels) would have a significant effect
Air quality	• On-going oil and gas development activities	Air emissions from the Project essentially

Environmental Component	Other Projects and Activities	Conclusions
	• Tankering from Valdez	would have no effects on air quality Projects in the past and present have caused essentially no deterioration in air quality or contribute measureably to global climate change.

Source: MMS 2000; 2001a; 2001b