BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT

REPORT OF THE SCIENTIFIC REVIEW PANEL

January 15, 2001

VOLUME TWO: APPENDICES

BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT:
VOLUME II – APPENDICES TO THE REPORT OF THE SCIENTIFIC REVIEW PANEL

(Volume I: BRITISH COLUMBIA OFFSHORE HYDROCARBON DEVELOPMENT:
REPORT OF THE SCIENTIFIC REVIEW PANEL)

Submitted to the BC Minister of Energy and Mines, Hon. Richard Neufeld

January 15, 2002

Panel Members:

David Strong (Chair)	David Strong is Professor in the School of Earth and Ocean Sciences at the University of Victoria. He was President and Vice-Chancellor at the University of Victoria from 1990 to 2000. He serves on the governing council and the executive committee of the National Research Council of Canada and the Research Council of the Canadian Institute of Advanced Research. Strong is the past Vice-President of Memorial University in St. John's, Newfoundland, where he was also special adviser to the President. He was a Member of the Standing Advisory Committee on University Research of the Association of Universities and Colleges of Canada, and served on British Columbia's Advisory Council on Science and Technology and the Newfoundland and Labrador Advisory Council on Science and Technology, among others.
Patricia Gallagher	Patricia Gallaugher is Director of Continuing Studies in Science and Director of the Centre for Coastal Studies at Simon Fraser University. She was a Professor of biology at Memorial University and is co-editor of a volume on marine conservation, *Waters in Peril*. Gallaugher participated in the North American Commission for Environmental Cooperation workshop on aquatic invasive species in the spring of 2001. Gallaugher has a PhD in bioscience from Simon Fraser University.
Derek Muggeridge	Derek Muggeridge is Dean of the Faculty of Science at Okanagan University College, where he is also Associate Vice-President of Research. He is President of Offshore Design Associates Ltd., which provides specialist services in offshore safety and wave and ice structure interaction. Muggeridge is a Member of the Awards Committee of the Science Council of British Columbia and a Member of the Canadian National Committee / Engineering Committee on Oceanic Resources. He was the Director of the Ocean Engineering Research Centre at Memorial University. Muggeridge has a Bachelor of Science from California State Polytechnic University, and a Master's of Science and a PhD in aerospace engineering, both from the University of Toronto.

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Appendix 1: Offshore Oil and Gas Scientific Panel – Terms of Reference

I. Introduction

October 19, 2001

The July 24, 2001 Speech from the Throne stated that Government would "explore the enormous opportunities of offshore oil and gas", and would appoint a scientific panel to "ascertain whether those resources can, in fact, be extracted in a way that is scientifically sound and environmentally responsible, with its initial findings being tabled by January 31, 2002".

This paper sets out the terms of reference for the Scientific Panel, and describes how Government will meet this commitment.

II. Context

Although the "offshore" includes all areas to the seaward, including the West Coast of Vancouver Island, "offshore oil and gas" refers primarily to the Queen Charlotte Basin, encompassing Hecate Strait, Queen Charlotte Sound and Queen Charlotte Strait. This basin is believed to have significant hydrocarbon resource potential. Although no commercial wells have been discovered, the Geological Survey of Canada currently estimates 9.8 bbo and 25.9 tcf of natural gas may be found in the basin.

British Columbia has restricted offshore oil and gas activity since 1959, with the exception of a brief period from 1965 to 1966. The Province has issued three separate orders in council (1959, 1966 and 1981), reserving the seabed floor off the Queen Charlotte Islands and Vancouver Island to the Provincial Crown.

A federal moratorium has also been in place since 1972. Negotiations between the Province and Canada on a "Pacific Accord" reached agreement on many topics by the late 1980's. However, significant issues related to First Nations, decision-making authority, financial matters, and the conditional status of the Accord remained outstanding when negotiations ended in 1988.

Concurrent with the Pacific Accord negotiations, Canada and the Province conducted a joint environmental assessment of offshore activities. In 1986, the assessment report, "Offshore Hydrocarbon Exploration", provided 92 recommendations on actions Government should take to ensure offshore oil and gas activity occurred in an environmentally sound manner. However, in 1989, as a result of public concerns over oil spills, the Province announced offshore drilling would be prohibited for at least five years; this was subsequently extended indefinitely.

III. Related Government Initiatives

The Ministry of Energy and Mines has contracted Jacques Whitford Environment Ltd. (JWEL), an international consulting firm, to undertake an independent study of offshore oil and gas technology based on the 1986 Report and a 1998 report prepared for, but never released by, the government of the day. JWEL will comment on scientific and socio-economic matters and, where appropriate, will identify "lessons learned" from other jurisdictions as well as "information gaps". The final report from JWEL is expected on October 19, 2001.

As a complementary initiative, Government has established a Northern Caucus to "consult with northern residents and community leaders" regarding a range of issues relevant to the North, including offshore oil and gas development.

IV. Mandate

The Scientific Panel will provide advice to the Minister of Energy and Mines on whether offshore oil and gas activity can be undertaken in a scientifically sound and environmentally responsible manner. In particular, the Panel will advise on:

- The scientific and technological considerations relevant to offshore oil and gas exploration, development and production;
- Further research or studies that should be undertaken to advance the "state of knowledge" on these considerations;

- Any specific Government actions that should be taken prior to a decision on whether to remove the current moratorium; and,
- Any specific conditions or parameters that should be established as part of a Government decision to remove the moratorium.

V. Tasks

The Scientific Panel will be expected to undertake the following tasks:

- review and provide analysis of the JWEL report;
- summarize public and stakeholder response to JWEL report;
- undertake additional literature reviews of relevant publications;
- solicit submissions and/or commentary by other relevant scientists or other experts as required; and
- prepare a final report for the Minister in accordance with the mandate above.

The Scientific Panel will not hold public meetings or hearings (these are the responsibility of the Northern Caucus). However, the Scientific Panel may invite relevant experts to provide information or opinions.

VI. Accountability

The Scientific Panel will be appointed by, and will provide advice to, the Minister of Energy and Mines. The Scientific Panel will operate independently from Government, but any decisions based upon its advice, particularly in relation to the current moratorium, will be made by Cabinet.

VII. Structure and Composition

The Scientific Panel will consist of three (3) internationally known and experienced academics, each with broad, relevant experience and expertise.

The Scientific Panel will have the capacity to include additional experts as "ex-offico" or "subject specific" members, as required to ensure that all relevant disciplines and perspectives are considered. These additional members would be appointed by the Minister of Energy and Mines on the recommendation of the Scientific Panel.

The Scientific Panel will receive project support from the Maritime Award Society of Canada (MASC). This support will include development of a project overview and workplan, coordinating meetings, managing submissions, and drafting work on the Scientific Panel's report to the Minister.

A senior official from the Ministry of Energy and Mines will be the liaison between the Ministry and the Scientific Panel.

Members of the Scientific Panel are identified in Appendix A. The MASC is described in Appendix B.

VIII. Timeframe

The Scientific Panel will deliver its final report to the Minister of Energy and Mines no later than January 15, 2002. The Panel will work through the following phases:

Phase 1: Preparation (conclude October 26, 2001)

- Post JWEL report on the Ministry website (University of Northern British Columbia will link into Ministry website)
- Finalize organizational arrangements for Scientific Panel and MASC

Phase 2: Investigation and Review (conclude December 15, 2001)

- Feedback on JWEL report collected from public, interest groups, etc.
- Panel to review and comment on JWEL Report
- Panel to investigate supplementary literature
- Panel to formulate recommendations

- Panel to seek additional submissions as required

Phase 3: Documentation and Submission (conclude January 15, 2002)

- Documentation of Report
- Documentation of non-technical executive summary
- Collation of Public Commentary
- Submission of Report to Government

APPENDIX A

Panel Members

David Strong (Chair)	David Strong is Professor in the School of Earth and Ocean Sciences at the University of Victoria. He was President and Vice-Chancellor at the University of Victoria from 1990 to 2000. He serves on the governing council and the executive committee of the National Research Council of Canada and the Research Council of the Canadian Institute of Advanced Research. Strong is the past Vice-President of Memorial University in St. John's, Newfoundland, where he was also special adviser to the President. He was a Member of the Standing Advisory Committee on University Research of the Association of Universities and Colleges of Canada, and served on British Columbia's Advisory Council on Science and Technology and the Newfoundland and Labrador Advisory Council on Science and Technology, among others.
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APPENDIX B

Maritime Award Society of Canada http://web.uvic.ca/masc/

The Maritime Awards Society of Canada is a registered charitable organization established to fund scholarships for Canadian university graduate students in marine and coastal affairs. At present MASC donations support scholarships at four universities: Victoria, Memorial, Dalhousie and Calgary. In addition, MASC has undertaken to provide a public service through annual workshops, public conferences, and other educational activities that are designed to raise awareness and enhance understanding of public policy issues related to the ocean in general and to Canada's coastal waters.

Appendix 2: Some Useful Websites

Government

- Alaska Oil and Gas Association: Current Issues, 1998. www.aoga.org/index
- American Petroleum Institute http://www.api.org/ehs/gulf/LGL%20Report.htm
- Atlantic Canada Petroleum Institute http://agc.bio.ns.ca
- Atlantic Canada Petroleum Institute http://www.acpi.ca/main.html
- BC Decision Support Services (DSS) of the Ministry of Sustainable Resource Management www.gov.bc.ca/dss.
- Bedford Institute of Oceanography http://www.mar.dfo-mpo.gc.ca/e/s_bio.html
- Canada-Nfld. Offshore Petroleum Board http://www.cnopb.nfnet.com/
- Canada-Nova Scotia Offshore Petroleum Board http://www.cnsopb.ns.ca/
- Canadian Association of Petroleum Producers – CAP http://www.capp.ca/
- Canadian Coast Guard http://www.ccg-gcc.gc.ca
- Canadian Environmental Assessment Agency http://www.ceaa.gc.ca/
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC): http://www.cosewic.ca
- Department of Fisheries and Oceans http://www.dfo-mpo.gc.ca/index.htm, http://www.dfo-mpo.gc.ca/frcc/
- Environment Canada http://www.ec.gc.ca/envhome.html
- Environmental Studies Research Funds http://www.esrfunds.org/home%20page%20eng.htm
- Global Ocean Observing System (GOOS). http://ioc.unesco.org/goos/
- Marine Environmental Data Service (Fisheries and Oceans Canada) http://www.meds-sdmm.dfo.gc.ca
- National Energy Board http://www.neb.gc.ca/
- National Research Council – Canada Institute for Scientific and Technical Information http://www.nrc.ca/cisti/cisti_e.shtml
- National Research Council Innovation Centre, Vancouver (fuel cell research) http://www.nrc.ca/icvan/
- Natural Resources Canada Geological Survey of Canada (Atlantic) http://www.nrcan-rncan.gc.ca/homepage/index.html
- Natural Resources Defense Council. http://www.nrdc.org
- Nova Scotia Department of Environment http://www.gov.ns.ca/enla/
- Nova Scotia Petroleum Directorate http://www.gov.ns.ca/petro/home.htm
- Oceans Act. http://www.pac.dfo-mpo.gc.ca/oceans
- Oceans and Coasts at Rio +10: http://www.udel.edu/CMS/csmp/rio+10

- Offshore/Onshore Technologies Association of Nova Scotia –OTANS http://www.otans.ns.ca/index.html
- Precautionary Principle http://www.dfo-mpo.gc.ca/cppa
- Public Review on the Effects of Potential Oil and Gas Exploration and Drilling Activities within Exploration. Cape Breton, Nova Scotia. http://www.publicreview.ns.ca/prceng/
- SeaMap: http://seamap.bio.ns.ca
- United Kingdom Offshore Operators Association http://www.oilandgas.org.uk/

Other Organizations/Associations

- American Association of Petroleum Geologists http://www.aapg.org/
- Canadian Association of Petroleum Producers http://www.capp.ca/
- Canadian Centre for Marine Communications http://www.ccmc.nf.ca/
- Canadian Geospatial Data Infrastructure www.geomatics.org/Report/techreport2/html)
- C-CORE http://www.c-core.ca/index.html
- Cook Inlet Keeper http://www.inletkeeper.org/
- EdgeNet http://www.edge-online.org/
- Environmental Impact of Offshore Oil and Gas Exploration and Production http://www.offshore-environment.com
- Fisheries Resource Conservation Council Joint Nature Conservation Committee – United Kingdom http://www.jncc.gov.uk/
- Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) http://gesamp.imo.org/no62/index.htm.
- Maritime Awards Society of Canada http://web.uvic.ca/masc
- NEPTUNE http://www.neptune.washington.edu http://www.neptunecanada.com/
- Newfoundland Ocean Industries Association http://www.noianet.com/
- Nova Scotia Petroleum Directorate http://www.gov.ns.ca/petro/
- Ocean Mapping Group, Univ. of New Brunswick http://www.omg.unb.ca/
- Offshore/Onshore Technologies Association of Nova Scotia http://www.otans.ns.ca/
- Oil Spill Intelligence Report http://www.cutter.com/osir/index.html
- Petroleum Communication Foundation http://www.pcf.ab.ca
- Scottish Fishermen's Federation http://www.sff.co.uk
- Sierra Club of Canada http://atlantic.sierraclub.ca/, eastern Atlantic http://www.sierraclub.ca/eastern/
- VENUS

Industry

- Alaska Oil and Gas Association (http://www.aoga.org)

- American Petroleum Institute http://www.api.org/ehs/gulf/LGL%20Report.htm
- Atlantic Canada Petroleum Institute http://www.acpi.ca/main.html
- Blue Energy Canada Inc. www.bluenergy.com.
- Canadian Association of Petroleum Producers http://www.capp.ca/
- Corridor Resources http://www.corridor.ns.ca/
- Mobil Oil Canada http://www.exxon.mobil.com/
- Hunt Oil http://www.huntoil.com/
- Imperial Oil Resources http://www.imperialoil.ca/
- Marathon Oil Company http://www.marathon.com/
- Newfoundland Ocean Industries Association http://www.noianet.com
- Offshore/Onshore Technologies Association of Nova Scotia –OTANS http://www.otans.ns.ca/index.html
- PanCanadian Energy Corporation http://www.pancanadian.ca/
- Petro-Canada http://www.petro-canada.ca/petro.html
- Shell Canada Limited http://www.shell.ca/
- United Kingdom Offshore Operators Association http://www.oilandgas.org.uk/
- Whiterose http://www.huskywhiterose.com/html/project_description/project/project2.html

Appendix 3: Lifting the moratoria[1]

The existing jurisdictional and regulatory setting.
The "existing state of affairs" is complex. It is necessary to distinguish among issues of constitutional jurisdiction, ownership, resource revenue sharing and regulatory responsibilities.

Geographically, issues of jurisdiction have been partly resolved but some uncertainty remains. At least as early as 1957, probably much earlier, British Columbia put forward claims to the offshore area, asserting Crown reserves over areas of the continental shelf out to the (then) boundaries of Canada's territorial sea. Initial industry activity in exploration and drilling took place in the 1960s in a muddled setting, with confusion not just between federal and provincial permitting and licensing, but also with federal departments of energy (Energy, Mines and Resources) and environment (initially Fisheries and Forestry) announcing conflicting positions with respect to drilling permits.

By now the jurisdictional questions have been settled to some extent. "Respecting federal-provincial constitutional jurisdiction over offshore areas, Supreme Court of Canada cases have determined [1967] that the federal government has, vis-à-vis British Columbia, exclusive legislative authority regarding all waters and seabed areas west of Vancouver Island and the Queen Charlotte Islands. The waters and ocean floor between Vancouver Island and the mainland have been held [1984] to be within provincial jurisdiction. There is legal uncertainty regarding federal-provincial jurisdiction over the waters and sea floor between Vancouver Island and the Queen Charlotte Islands (Queen Charlotte Sound) and the waters and sea floor landward of the Queen Charlotte Islands (Hecate Strait)." (Cumming and McDorman, p.7)

In a footnote to the above comment, it is noted that in 1981 British Columbia declared that the waters and seabed landward of the straight baselines and fishery lines established along the west coast (the area of Hecate Strait and Queen Charlotte Sound) were a provincial Inland Marine Zone. (BC Order in Council 1347, 4 June 1981, made pursuant to section 87(g) of the Petroleum and Natural Gas Act, Rev. Stat. of BC 1979, ch 323). It is also speculated that "a clear articulation by the federal government of Canada that the waters of the Queen Charlotte Sound and Hecate Strait were internal waters would provide considerable strength to the BC position that the seabed of these waters, and the possible hydrocarbon resources located therein, are under provincial jurisdiction" (loc.cit.).

Thus it appears that the federal government would have authority to issue licenses or rights in the territorial sea, west of the low water mark of the outer coastline, that is, roughly, west of a line running north along the western side of Vancouver Island and the Queen Charlotte Islands, while in the internal waters landward of such a line, though the ownership by the province may be acknowledged, activities would be subject to joint jurisdiction. In similar situations of confused or overlapping jurisdiction, companies have dealt with the problem by holding both federal and provincial licenses, and governments have coordinated their issue of licenses correspondingly. (It should be emphasized, however, that such licenses now do not confer any right to specific exploratory or production activities; they merely secure the exclusive right of the licensee to apply for authorization to undertake such specific activities in the designated area or parcel of land.)

"The aboriginal rights component of the Canadian Constitution has implications for stakeholders that are potentially as significant as those arising from considerations of federalism. This is because offshore oil and gas projects may well be challenged in court on the basis that they infringe the aboriginal rights of First Nations in the area….In the context of offshore drilling, it is fishing rights that are most likely to be at issue. Aboriginal title could also be implicated, although this is considerably less likely…An offshore oil and gas project might interfere with an aboriginal fishing right if it is located in waters where an aboriginal fishing right is exercised and in a manner that potentially threatens the fish habitat…Both the federal and provincial governments are bound by s. 35 [of the Constitution Act]. Accordingly an infringement would

[1] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Rod Dobell and Claire Abbott, University of Victoria – January 2002.

occur where either government approves an offshore oil and gas project that (a) jeopardizes the fish supply which an aboriginal group has the constitutional right to fish or that (b) is located in waters subject to aboriginal title.…[To justify such an infringement] meaningful consultation with aboriginal people, conducted in good faith, would almost certainly be required….In fact, consultation with affected aboriginal peoples is already a legal requirement under environmental legislation….(Extracts from "Offshore Oil and Gas and British Columbia: The Legal Framework. T. Murray Ranking, October 2, 2001.)

With respect to regulatory responsibilities, however, the federal government has legislative authority respecting "navigation and shipping"; "beacons, buoys and lighthouses" and presumably other structures or platforms; fisheries; and aspects of marine pollution. At the same time, the provincial government has legislative authority over all lands and mineral resources "in the province" and, more generally, through "property and civil rights", all activities that take place in the province. (Cumming and McDorman, p. 9). Such authorities would be exercised simultaneously by both governments in all the geographical regions discussed.

It should be noted that the Oil and Gas Commission was created in British Columbia in 1998 to regulate exploration and production activities onshore in British Columbia, but the legislation is silent on any role with respect to offshore activities. A cursory reading of the mission and purposes shows nothing to exclude application of its powers to offshore resource questions. [See http://www.ogc.gov.bc.ca/whoweare.asp]

Existing provisions for environmental review

It seems reasonably clear that any proposal by a company or consortium of companies to undertake seismic surveys or exploratory drilling would trigger a review under the Canadian Environmental Assessment Act, and probably also under the BC Environmental Assessment Act. (It is not so clear that a bid for a license or exploration rights itself would do so.) Requirements for license or approvals under the Fisheries Act, the Navigable Waters Act, the NEB Act, or the Canada Oil and Gas Operations Act (among possibly many others) would trigger a requirement for an environmental assessment.

It should be noted that a mandated five-year review of the CEAA (1995) led to Bill C-19 being tabled in March, 2001, with proposed amendments to the Act; the Bill received second reading in June, and the Standing Committee on Environment and Sustainable Development began its review of the Bill on December 4, 2001. The Minister's report to Parliament on the review process suggests little dramatic change to existing procedures, but emphasizes the importance of the joint review processes.

In British Columbia the present administration has indicated that as part of its core services review it is reviewing its environmental assessment processes and the present British Columbia Environmental Assessment Act along with many other legislative or regulatory provisions in the arena of land and resource planning, management and use.

The Regulatory Roadmaps Project of Erlandson and Associates provides detailed guides to the existing regulatory approval processes for oil and natural gas exploration and production in various offshore areas. [See http://www.oilandgasguides.org . Unfortunately there exists no such document for BC, but those which have already been created to describe the situation on the Atlantic and Arctic coasts illustrate well enough the extraordinary complexity of the approval and oversight processes involved.

Within the overall framework of a Canada-Wide Accord on Environmental Harmonization negotiated within the Canadian Council of Ministers of Environment, Canada and British Columbia have signed a bilateral harmonization agreement on environmental assessment cooperation. Under this agreement, for any proposal requiring both a federal and a provincial environmental assessment, a harmonized review process would be developed, with the goal of meeting all the requirements for review, federal, provincial or other, through a single unified process. The agreement presently in force provides that where both CEAA and BCEAA are triggered, the joint review process will be undertaken and completed using the BC environmental assessment process.

This present sub-agreement with BC under the CCME Harmonization Framework expires in April, 2002, and must be extended or re-negotiated. In the present setting, with both federal amendments in process and provincial review of its environmental assessment legislation and processes underway, re-negotiation of the harmonization sub-agreement may be difficult or delayed, and hence the provisions for a joint process may be difficult to establish for some time.   However, none of this need come into play until there is some industry application to consider. And not all activity necessarily triggers a requirement for review under both Acts; it will be necessary to identify what sorts of applications do so.

As noted below, it seems likely that the process of negotiating some form of Pacific Accord paralleling the existing Atlantic Accords implemented with both Nova Scotia and Newfoundland and Labrador may involve creation of mirror legislation, with either a continuing joint Offshore Board or provision for project-specific independent review panels to carry out necessary environmental reviews and assessments, all entailing increasingly extensive public hearings.

Such a coordinated environmental assessment was carried out for the Sable Island Offshore Energy Project. A five-person review panel was appointed in 1996; the joint review report was released in October 1997. The various regulatory agencies having jurisdiction adopted various recommendations or conditions of the review panel prior to giving their approval to project proposals. (It's worth noting that the precedent of NEB leadership in the Sable Island review process reflected the crucial character of the interprovincial pipeline involved, a matter beyond the powers of the Offshore Board itself. A similar situation does not exist here, so the basis for NEB involvement in a similar review panel might be somewhat different.)

At another level, within the federal government, it appears that any federal move to end the existing policy of refusing to entertain applications for new drilling licenses or for exploratory activity under existing licenses offshore British Columbia would be subject in the first instance to the 1999 Cabinet Directive on Strategic Environmental Assessment of Policy, Plan and Program proposals. This Directive, intended to provide the overarching policy review to complement the legal framework provided by the Canadian Environmental Assessment Act for environmental assessments on projects requiring federal government permits or authorizations, requires that a strategic environmental assessment be undertaken on any general policy or program proposal submitted to a Minister or to Cabinet for approval when implementation of the proposal may result in important environmental effects.

It is not clear whether similar requirements for formal strategic environmental assessment at a policy level exist in BC, but presumably any decision to move forward with a general measure to 'lift the moratorium' will require a Cabinet Submission by the Minister of Energy and Mines; such a Cabinet Submission will require attention to implications with respect to environment and sustainable development. Thereafter provisions of the BCEAA will presumably require that any specific project proposals be reviewed, again presumably under the provisions for a fully harmonized process.

The Moratoria

With this understanding of the current situation with respect to jurisdictional questions, regulatory authorities and assessment processes, we can move on to ask what is the present moratorium, and where matters would rest if it were ended.

The answer seems to be that the present 'moratoria' on exploration for or development of hydrocarbon resources offshore British Columbia currently exist essentially as a legacy of a variety of announcements going back over four decades. As a result of this legacy, both the federal and provincial governments are understood to be unwilling to consider any new claims or applications for licenses to areas of seabed offshore British Columbia, or to entertain proposals for activity under any existing licenses. At the same time, it seems that any existing license holders have been exempted from any obligations to undertake activities as a condition of their license, and thus are in the position of having their existing claims protected, in effect, without the usual obligations to work them.

A fascinating glimpse into the origins—or at least early stages—of the debate is offered by an exchange in Hansard for April 20, 1972. Tommy Douglas, at the time MP for Nanaimo-Cowichan-The Islands, questions whether oil drilling permits issued by the Minister of Energy, Mines and Resources (Donald MacDonald) to Petrotar Development covering 2.7 million acres in Queen Charlotte Sound had or had not been revoked. He noted that David Anderson, at the time MP for Esquimalt-Saanich, had assured the public that no such permits would be issued for exploration of offshore areas without the approval of the Minister of the [then new] Department of the Environment. The Minister of Environment himself [Jack Davis] was quoted as saying there would be action to recover the permits (though it appears this never happened).

In response, Jack Cullen, Parliamentary Secretary to the Minister of Energy, Mines and Resources, enunciated what might be taken as the federal government policy at the time: “With the concurrence of my Minister (the Minister of Energy, Mines and Resources), the Minister of Environment (Mr. Davis) announced in Vancouver on March 13 (1972) that exploration and drilling for oil would be excluded from sensitive offshore zones. Our departments will work together on definition of these offshore zones….If any of Petrotar’s permits should fall within environmentally sensitive zones, then we will be discussing with that company the kinds and conditions of work which will not be allowed. I should like to confirm the government’s position that subject to this zoning, exploration and drilling will be encouraged in the offshore frontier in strict adherence to regulations currently enforced by my department and judged to be among the most stringent anywhere in the world.” (Hansard, pp 1507-1508, April 20, 1972)

Subsequently the federal government position hardened, it seems. Some accounts refer to a mythical 1972 federal Order in Council establishing formally a moratorium on oil and gas drilling, on the recommendation of the Commons Special Committee on Environmental Pollution founded and chaired by David Anderson. In fact the report of this committee dealt with fears of oil spills from tankers traveling the West Coast from Alaska to Washington, carrying oil from the newly-exploited Prudhoe Bay fields. But the expression of these concerns did raise questions about the inconsistency of Canadian battles with the United States over tankers and oil spills while proposals for seismic exploration (perhaps using dynamite) and applications for drilling licenses in Georgia Strait or Queen Charlotte Basin were being routinely approved by another arm of the same Canadian federal government.

An article in the December 31, 2001 issue of *The Globe and Mail* contains the following account of the federal decision at that time. “Mr. Anderson [federal Minister of Environment David Anderson] said he was also personally responsible for the federal moratorium on drilling for oil and gas off the West Coast. He had urged former prime minister Pierre Trudeau to impose the moratorium, arguing that Canada could not logically express concern [in the US] about oil-tanker traffic while allowing oil companies to drill for oil in the same water. The moratorium was imposed in 1972.”

Extensive searching, apparently by many people, has not turned up any 1972 Order-in-Council, despite the fact that its existence is asserted in authoritative journals (but with citation only to secondary sources which themselves cite no sources.)

In a personal conversation January 13, 2002, the Minister indicated that he knew of no Order in Council or other formal instrument establishing the moratorium. He noted that many people misunderstand the nature of the moratorium: in fact its central effect is not a prohibition on drilling activity, it is to lift from licenseholders any obligations to undertake work under those licenses, since the government would not be prepared to approve such activities in any case.

In one version, it all seems fairly clear. In the Sierra Legal Defence Fund publication *A Crude Solution* it is said that “the legal mechanism invoking the moratorium is quite simple and could easily be changed…” A box in the text explains the situation as seen by SLDF: “The current provincial moratorium traces back to a 1981 Order in Council, which reserved lands offshore to the province and placed a moratorium on oil drilling. All that is required to lift this moratorium is a new Order in Council. The federal moratorium is even easier to lift. But until such time as it is is, no offshore activity can proceed. ‘The [federal] moratorium is just an administrative agreement between the federal and the provincial government’ Heather Dabaghi, an adviser on land management for the federal Department of Natural Resources, explained in a Monday Magazine article in May, 1995. ‘There’s nothing set out in legislation, but periodically we announce that the moratorium is still in place.’

It seems likely that this description refers to a federal government undertaking (following a 1989 BC announcement) not to proceed with authorization of further activity until British Columbia was prepared to do so, and perhaps it is the same understanding that gives rise to references to an alleged annual letter from an unidentified federal official to licenseholders assuring that a lack of activity would not jeopardize their licenses.

Telephone conversation with an official in the Frontier Lands Management group of Natural Resources Canada, which is responsible for the administration of the federal offshore lands, confirms that in fact the present situation is simply the policy of the Minister that the Department will not entertain applications for new licenses, or for work under existing licenses, and has relieved existing licenseholders of their responsibility to undertake the work obligations normally present as a condition of holding a license. Initially this exemption from work requirements had to be extended and confirmed annually; under present regulations this is no longer the case. A decision by the Minister to initiate a land sale, or to invite companies to renegotiate existing licenses, would effectively end the federal moratorium. But it is the policy of the federal government not to initiate such measures without the concurrence of the provincial governments concerned.

Thus the administrative history of the federal moratorium seems somewhat cloudy: it is not clear that any single piece of paper exists to establish or describe the federal moratorium. There is a straightforward process to repeal an Order in Council if one existed. Though there seems clearly to be a policy, it is not yet clear whether any explicit policy statement exists. Spokespeople for Environment Canada insist, and Minister Anderson confirms, that his position is clear: If there were a concrete site-specific proposal advanced, it would have to meet all the stringent requirements of the existing legislation as to environmental assessment and review, including the responsibility to prepare all the studies necessary to such a review, but there would be no bar to consideration of such a proposal. New proposals could be submitted, in other words, through the relevant review procedures, which themselves would have the task of establishing that the proposed activity would not have unacceptable environmental or social impacts.

The case in British Columbia is also somewhat ambiguous. As noted above, a 1982 Order in Council defined a provincial Inland Marine Zone and established regulations banning drilling in it (Reg 10/82). Following the extensive 1986 review of Chevron's proposals for a program of exploratory drilling, consideration was given to lifting that prohibition, but the Nestucca Barge and Exxon Valdez oil spills intervened. The Province announced in 1989 that there would be no drilling for at least five years.

In 1994, a new Order in Council (OIC 248) and a new regulation (55/94) revised Regulation 10/82, dropping Note 2 to Schedule 2. And so, it seems, any formal prohibition on drilling offshore ended. Presumably British Columbia now could simply declare that there is no moratorium, that the provincial government is also willing to consider applications under the existing legislative and regulatory regime.

It thus appears that the moratoria could be 'lifted' either actively, as a positive decision by either government, or by implication, simply by federal and provincial governments indicating a willingness to entertain new applications for exploratory activity under the existing regulatory regime, or new applications for licenses to undertake such activity. It appears inevitable that any such application would trigger both the Canadian Environmental Assessment Act and the BC Environmental Assessment Act (as discussed below).

As noted above, to bring clarity to the regulatory regime under which oil or gas exploration or development would proceed, there would have to be mutual agreement in bilateral discussions, with a comprehensive accord on commitments to a process for environmental review, perhaps with mirror legislation governing administration, regulation and environmental review, perhaps with some new Joint Board, perhaps involving augmented responsibilities assumed by British Columbia's existing Oil and Gas Commission. Such an accord must also address resolution of First Nations claims and concerns.

In the case of British Columbia, major questions about resource revenue sharing with aboriginal communities will have to be addressed along with federal-provincial accords on resource revenues, in negotiations separate from any required environmental reviews. The potential difficulty of any such negotiations might be illustrated by the fact that the National Round Table on the Environment and the Economy was unable to find any consensus around the 'free entry' provisions applying to mineral rights in the North West Territory. (See the State of the Debate report on Aboriginal Communities and Non-Renewable Resource Development, NRTEE, 2001, which also provides useful illustrations of provisions for equity participation by aboriginal communities, employment guarantees and similar provisions related to economic benefits, all features of the approval processes and operational procedures now in place on the East Coast.)

In negotiating a Pacific Accord, there are some other lessons to be learned from recent experience in Atlantic Canada. First, on design issues, the Government of Nova Scotia in November 2001 introduced legislation to separate the industry promotion responsibilities of the Offshore Board from potentially conflicting responsibilities for health, safety and environmental integrity. Second, on resource sharing questions, it obviously will be necessary to take into account the interactions with other features of fiscal federalism, particularly the workings (in BC, the non-workings) of the Equalization Program.

Appendix 4: Definitions Scientific/Technical Methods Related to Offshore Exploration[2]

"Geophysical" work involves the indirect measurement of the physical properties of rocks in order to determine the depth, thickness, structural configuration or history of deposition and includes the processing, analysis and interpretation of material or data obtained from such work. Specific geophysical operations measure or investigate, by indirect methods, the subsurface of the earth for the purpose of locating petroleum or of determining the nature of the seabed and subsurface conditions at a proposed drilling site or of a proposed pipeline route, and include seismic surveys, resistivity surveys, gravimetric surveys, magnetic surveys, electrical surveys, geochemical surveys, and any work preparatory to that measurement or investigation, such as field tests of energy sources, calibration of instruments and cable ballasting, but do not include a velocity survey or a vertical seismic survey that is not a walkaway vertical seismic survey.

"Geological" work is defined as work, in the field or laboratory, involving the collection, examination, processing or other analysis of lithological, paleontological or geochemical materials recovered from the seabed or subsoil of any portion of the offshore area and includes the analysis and interpretation of mechanical well logs.

"Geotechnical" work is defined as work, in the field or laboratory, undertaken to determine the physical properties of materials recovered from the seabed or subsoil of any portion of the offshore area (dealt with further in Chapter 4 of this Review).

"Environmental" study is defined as work pertaining to the measurement or statistical evaluation of the physical, chemical and biological elements of the lands, oceans or coastal zones, including winds, waves, tides, currents, precipitation, ice cover and movement, icebergs, pollution effects, flora and fauna both onshore and offshore, human activity and habitation of any related manners.

Marine multichannel and high-resolution single channel seismic surveys have been used to understand the structure and basic stratigraphy of BC offshore basins, fault structures and other relevant features. **Gravity and magnetic** surveys and studies have been used for the development of geological and tectonic models. **Geothermal** studies provide data for crustal temperatures, tectonic models, and basin organic maturation. **Structural and geochemical** studies of Tertiary volcanic rocks contribute to an understanding of the tectonic origin and formation of basins, their subsidence and uplift, and tectonic associations with plate interactions along subduction zones and transform faults such as the Queen Charlotte Fault. **Seismic monitoring** of earthquakes is essential for understanding seismic hazards. The Queen Charlotte Basin and margins are particularly complicated and have been subjected to all of these techniques and disciplines. Given that the QCB has been recognized as the area with greatest potential for offshore oil and gas, it commands the greatest attention in this review.

Multi-beam Swath Bathymetry is the current state of the art technology for determining seafloor morphology and characterization. That is, it provides an indication of materials present on the ocean bottom, including bedrock, sediment distribution, and by extension and interpretation, areas of more or less risk from submarine slumping, liquefaction, turbidity currents, etc. Other techniques, such as **side-scan sonar, sub-bottom profiling and sampling** are routinely incorporated into the final interpretation. Surveys have been done for selected areas of the BC offshore, most locations being driven by population centres which might be most at risk from related hazards such as disruption of communications or pipelines. These surveys are done in cooperation with the Canadian Hydrographic Service, and cost about $100,000 per month, with e.g. a ~60x60 km map requiring three months. **Open File 2195** is a 1:250,000 scale interpretation of possible geoscience seafloor hazards in Hecate Strait/Queen Charlotte Sound. Larger scale (1:50,000, 1:20,000) interpretations will require substantially more data except in selected areas such as the sponge complexes which have been studied in some detail.

[2] Many entries are taken from Canada-Newfoundland Offshore Petroleum Board.

Earthquake Monitoring (Based on interview with Dr. Gary Rogers, Geological survey of Canada)

It's very clear that the science for understanding earthquakes is highly sophisticated world-wide, and for the BC offshore fairly advanced in specific terms. Prior to 1970 there were no seismographs on Queen Charlotte Islands, only one until the mid-80s when twelve were installed. Although six were removed during the down-sizing of 1996, the remaining six still leave QCI fairly well-instrumented, given that there are only ~100 in all of Canada. Using more distant seismographs, the catalogue of potentially damaging earthquakes in the region, those of magnitude 6 or greater, is complete since 1917. Nevertheless, we can't fail to compare the small number of nine QCI seismographs with the 700 deployed in the analogous region of California.

There is a fundamental distinction between the deterministic, or site-specific knowledge of earthquake hazards, and the broader-based probabilistic understanding. The earthquake hazard in the Queen Charlotte region has been determined and is published in the Geological Survey of Canada's national seismic hazard maps. These hazard maps are used to define engineering design criteria for the National Building Code, and to provide information for preliminary design criteria for specialized structures. The ongoing research for the next generation hazard maps indicates that there will be no increase in seismic hazard in the Queen Charlotte Islands region over the present maps.

The Canadian Standards Association has design standards for offshore structures (A Preliminary Standard S471-M1989 B **GENERAL REQUIREMENT: DESIGN CRITERIA, THE ENVIRONMENT, AND LOADS, Part 1 of the code for the Design, Construction, and Installation of Fixed Offshore Structures@** - ISSN 0317-7874; published in May 1989 by Canadian Standards Association). These standards are currently undergoing review to be consistent with the format of the next generation seismic hazard maps. Regulators may require more detailed seismological or geotechnical investigations to define final engineering design criteria for structures associated with offshore production.

Appendix 5: Offshore Oil and Gas Approvals in Atlantic Canada[3]

Offshore Oil and Gas Approvals in Atlantic Canada
A guide to regulatory approval processes
for oil and natural gas exploration and production
in the Newfoundland Offshore Area
June 2001

The Regulatory Roadmaps Project

Erlandson & Associates Consultants

The preparation of this Guide was undertaken jointly by the Atlantic Canada Petroleum Institute, and Erlandson & Associates Consultants, Victoria, British Columbia.
Written and compiled by Reade Davis in St. John's, Newfoundland, with assistance from Gloria Chao in Halifax, Nova Scotia.

Document preparation by LB Word Works, Victoria, British Columbia.

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Table of Contents
Newfoundland Offshore Guide – June 2001 v
CONTENTS

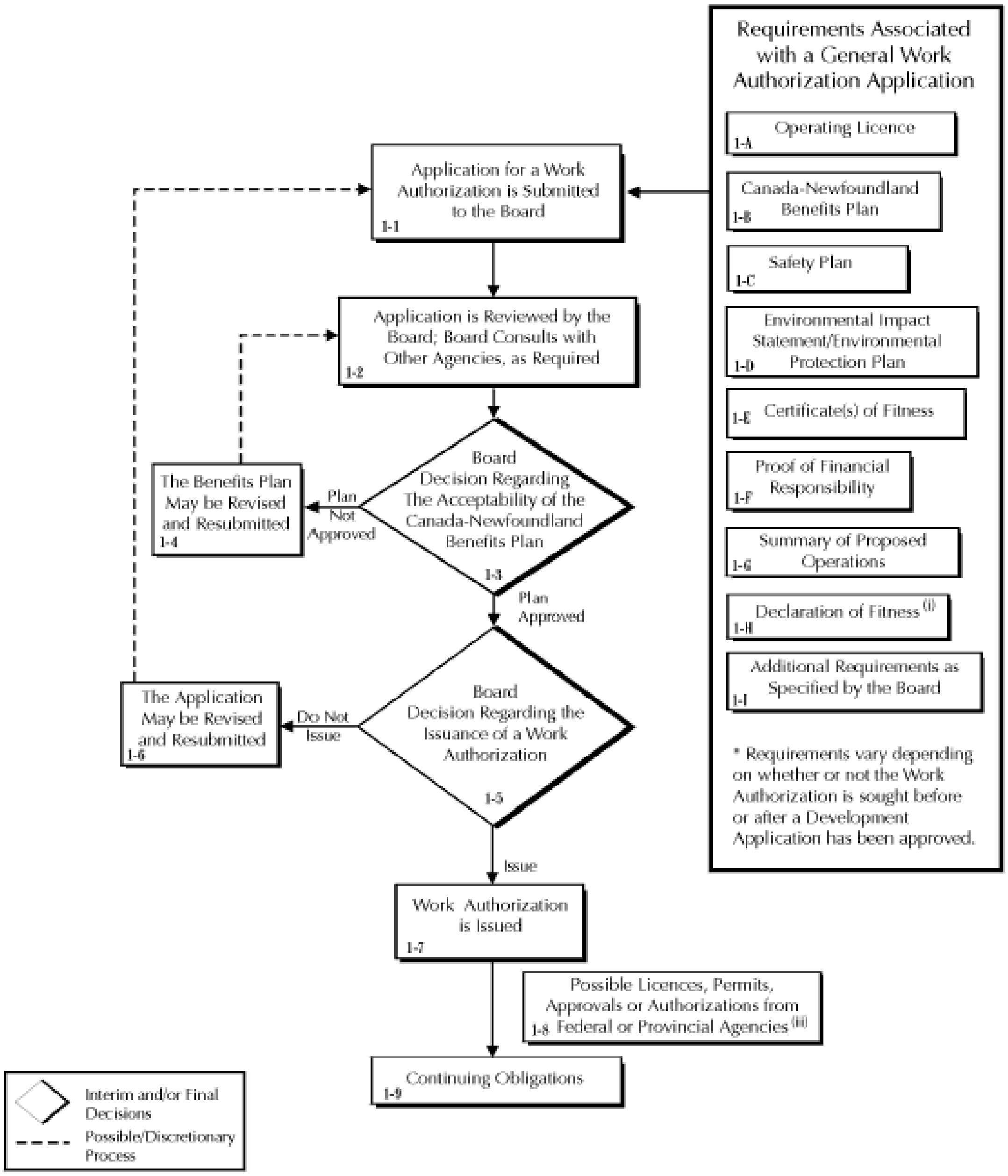
[3] Because of the importance of the approval process that relates to offshore exploration in other jurisdictions, the Panel has reproduced here the Table of Contents for *Offshore Oil and Gas Approvals in Atlantic Canada*, as well as several schematic diagrams outlining specific steps at each stage of an offshore program.

Table of Contents
viii Newfoundland Offshore Guide – June 2001

Table of Contents
Newfoundland Offshore Guide – June 2001 ix

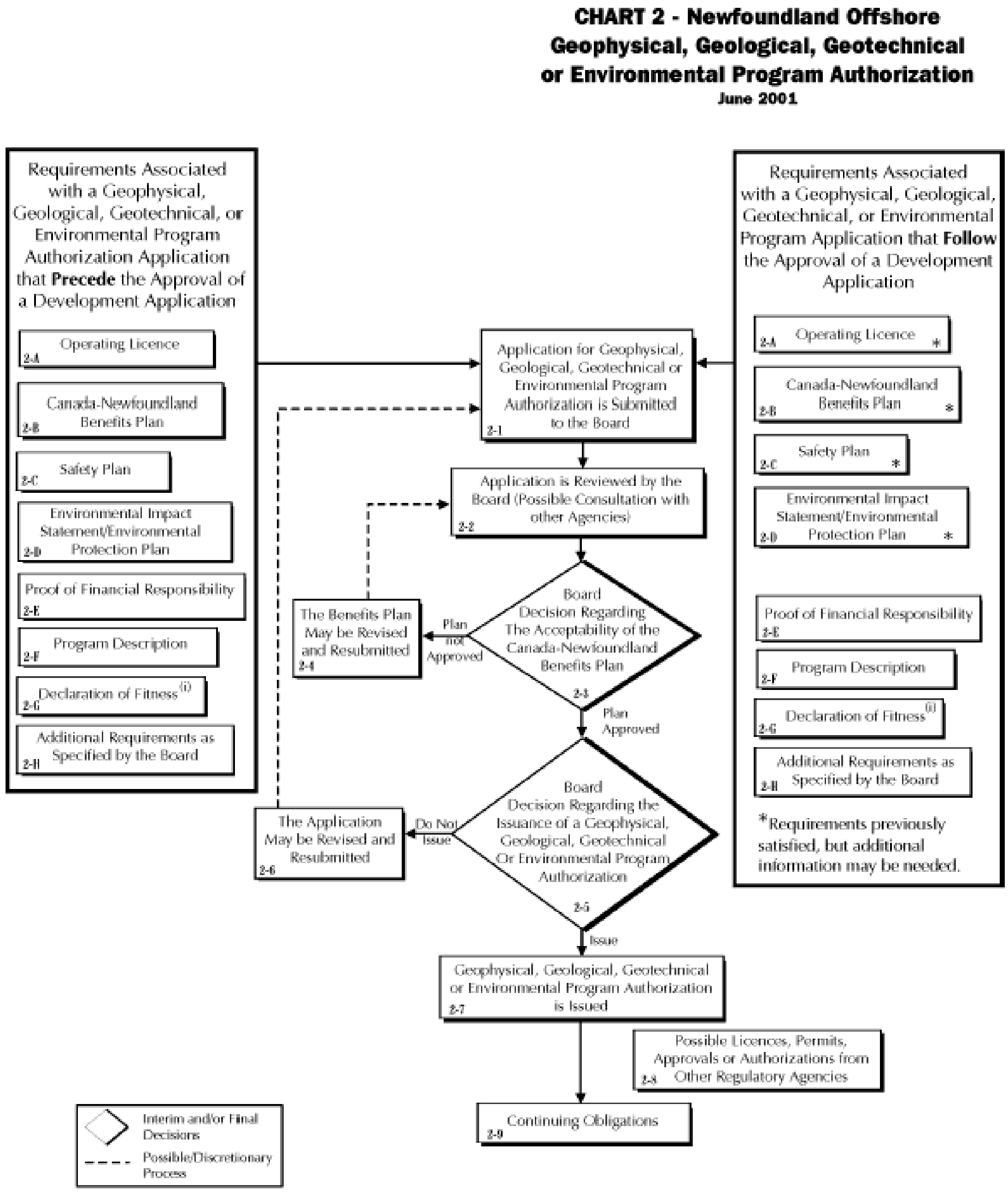
Table of Contents
LIST OF APPENDICES

CHART 1 - Newfoundland Offshore CNOPB's General Work Authorization Process June 2001



(i) In practice, the Declaration of Fitness is only submitted to the Board when all other requirements have been fulfilled.

(ii) Provincial authorizations may be required in a circumstance where there is bridging of offshore and onshore activities.



(i) In practice, the Declaration of Fitness is only submitted to the Board when all other requirements have been fulfilled.

Appendix 6: Geologic Situation and Hydrocarbon Potential of Queen Charlotte Basin[4]

Introduction

The Queen Charlotte Basin (QCB) between the BC mainland and the Queen Charlotte Islands is expected to have substantial petroleum accumulations (Figure 1). Speculative estimates of the oil in place center around 1.5 billion cubic meters (m^3) or 9.8 billion bbl (e.g, Hannigan et al., 1998). They estimate natural gas in place to be around 730 billion cubic meters (m^3) or 26 Tcf. Recoverable reserves are lower possibly 400 million cubic meters (m^3) or 2.5 billion bbl oil and 550 billion cubic meters (m^3) or 20 Tcf gas (Tables 1 and 2).

Queen Charlotte Basin Region

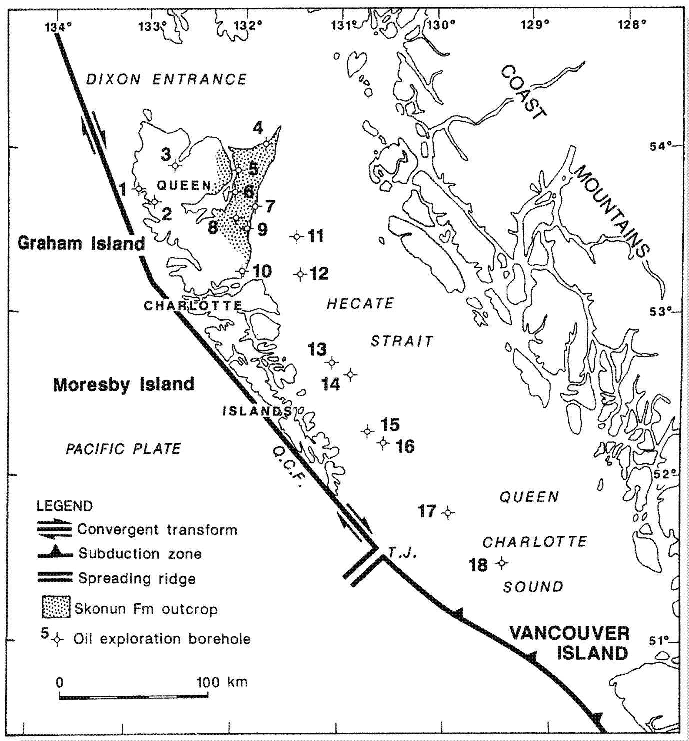


Figure 1. Location map of Queen Charlotte Basin (Hecate Strait) showing the major tectonic features and 18 previous drillhole locations (from Woodsworth, 1990)

Based on National Energy Board figures, these potential oil and gas resources are significant on a national scale as shown in Tables 1 and 2. However, whether or not these estimates are realistic will require considerably more exploration effort.

Table 1. Comparison (Discovered Marketable Resources)

Location	Oil (10^6 m^3)	Natural Gas (Tcf)
QCB	400*?	20*?
A. Canada	4,555	198
B. WCSB	2957	159

[4] Submission to Dr. D.S Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

C. Frontier	528	33
D. BC conventional	129	20

*? = Speculative estimation

Table 2. Comparison (Ultimate Resources)

Location	Oil (10^6 m^3)	Natural Gas (Tcf)
QCB	730*?	26*?
A. Canada	9,177	733
B. WCSB	3,623	335
C. Frontier	4,255	303
D. BC conventional	184	50

*? = Speculative estimation

The QCB is the largest Tertiary basin on Canada's West Coast. It represents an area of approximately 80,000 km^2 (500 km long, 150 - 200 km wide) containing:

1. Queen Charlotte Islands;
2. Offshore areas of Hecate Strait
3. Queen Charlotte Sound
4. Dixon Entrance

The QCB is bounded to the south and north by Vancouver Is. and Alaska. It is terminated to the east by the Coast Plutonic Complex and to the west by the large Queen Charlotte Fault that separates the North American Plate from the Pacific Plate (Figure 1, from Woodsworth, 1990).

To date, 18 exploration wells have been drilled (shown in figure) in the QCB, with 8 offshore in the Hecate Strait and 10 on Graham Island. These wells, combined with the regional geophysical seismic studies and land-based geology are the basis of the prospectivity projections. Estimates are based on abundant reservoir strata, presence of potential source rocks, numerous structural traps, and common occurrence of oil and gas shows.

The Neogene portion of the Queen Charlotte Basin is expected to contain 80% of region's total petroleum resource volume and nine of the ten largest fields. Geographically speaking, most prospective areas are southern Hecate Strait, followed by Queen Charlotte Sound, eastern Graham Island, northern Hecate Strait and Dixon Entrance (Figure 1). High potential for southern Hecate Strait based on abundant Neogene reservoir strata, numerous large structural features, and presence of Neogene and Jurassic source rocks. Outside the basin margins, western Graham Island and adjacent shelf areas have some potential targets, but very little petroleum potential is expected overall in the onshore/inter-island areas of the southern Queen Charlotte Islands and adjacent Pacific continental shelf.

Basic Stratigraphic Sequence – Key Geologic Units

The QCB is termed a Tertiary Basin, i.e., younger than 65 Ma, but in fact some of the more interesting geologic unit are older. The basic stratigraphic framework is shown in Figure 2 (from Dietrich, 1995) and in Table 3.

The so-called basement of the basin, i.e., the floor unit for any expected petroleum formation and occurrence, is the several thousand meters of volcanics comprising the Triassic Karmutsen Formation (Ladinian-Carnian age, ca. 230 Ma, up to 4,600m thick)

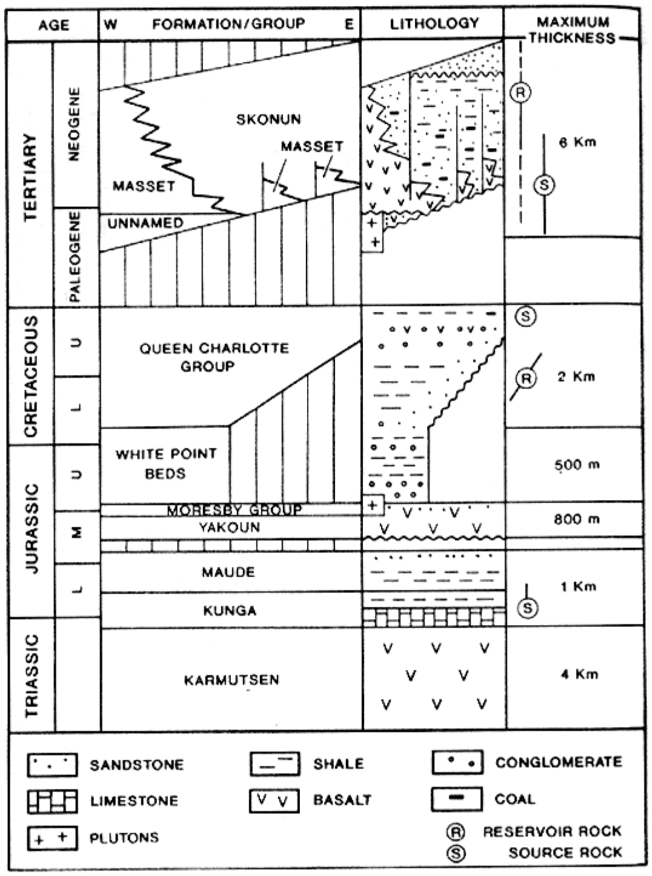


Figure 2. Geological stratigraphic sequence of Queen Charlotte Basin (from Dietrich, 1995)

The Karmutsen strata are overlain by up to 600m of Upper Triassic and Lower Jurassic limestones, sandstones, and shales of the Kunga groups (Carnian-Norian-Hettangian age, ca. 200-225 Ma). This is followed by 300m the deep marine, shale to siltstones, sandstones with mudstones of the Lower Jurassic Maude Gp (Sinemurian, Pliensbachian, Toarcian, ca. 185-200 Ma). These shallow to deep marine rocks Kunga and Maude Gp are some of the best oil prone potential source rocks in the region.

These Lower Mesozoic successions are uncomformably overlain by several hundred meters of volcanic and volcaniclastic rocks of the Middle Jurassic Yakoun and Moresby groups (Aalenian-Tithonian, ca. 144-185 Ma, 1000m). Uncomformably overlying these groups are up to 2500m of Upper Jurassic-Cretaceous sandstone-shale-conglomerate of the Longarm Fm (Berriasian through Aptian, ca. 98-144 Ma, 450 m) and Queen Charlotte Group (Albian through Masstrichtian, ca. 68-98 Ma, 2500 m). Selected intervals of the

Table 3. Basic Stratigraphy of Queen Charlotte Basin

L. Triassic: Ladinian, Carnian, ca. 230 Ma

Karmutsen Fm: up to 4600 m - Effective Basement

- basalts (greenstone), minor limestones, argillites

L. Triassic/E. Jurassic: Carnian, Norian, Hettangian, ca. 200-225 Ma

Kunga Gp: ca. 600 m - Source Beds

- shallow to deep marine, limestones to siltstones, argillite, tuff

E. Jurassic: Sinemurian, Pliensbachian, Toarcian ca. 185-200 Ma

Maude Gp: ca. 300 m - Source Beds

- deep marine, shale to siltstones, sandstones with mudstones

Mid/L. Jurassic: Aalenian through Tithonian, ca. 144-185 Ma

Yakoun and Moresby Gp: ca. 1000 m – poor Reservoir Rocks

- shallow, volcanics, conglomerates, sandstones, siltstones

E. Cretaceous: Berriasian through Aptian, ca. 98-144 Ma

Longarm Fm: ca. 450 m – limited Reservoir Rocks

- shelf, hard sandstones to soft sandstones, shale conglomerates

Mid/L. Cretaceous: Albian through Masstrichtian, ca. 68-98 Ma

Queen Charlotte Gp: Haida, Skidegate, Honna & unnamed Fm

- ca. 2500 m – limited Reservoir Rocks

- sandstones, siltstones, mudstones, conglomerates, volcanics

E. Tertiary: Paleogene, ca. 23.7-66.4 Ma

Unnamed volcanics/flows and sedimentary rocks: ca. 1000 m

- subareal, marine – limited Reservoir Rocks

- shallow basalts, andesites, conglomerates, black shale, sandstones

L. Tertiary: Neogene, ca. 1.6-23.7 Ma

Masset Fm: up to 4,000 m, basalts, rhyolite flows, pyroclastics

- marine and terrestrial – good Reservoir Rocks

Skonun Fm: ca. 5,000 m - sandstones, shale, conglomerates, lignite

- marine and terrestrial– good Source and Reservoir Rocks

Queen Charlotte Group have good reservoir characteristics, the most promising being shallow-marine sandstones and granule conglomerates in basal part of the formation.

These strata were deposited along NW-SE paleo-shorelines in the Queen Charlotte Islands and western parts of Dixon Entrance, Hecate Strait, and Queen Charlotte Sound (Haggart, 1991; Lyatsky and Haggart, 1993). Fogarassy and Barnes (1991) described outcrop reservoir characteristics with porosity averaging 5 to 10%, and permeability considered fair to good.

The lower Tertiary rocks (Paleogene, ca. 23.7-66.4 Ma) are largely unnamed volcanics/flows and sedimentary units. These ca. 1000 m subareal and marine rocks have components of conglomerates, black shale, sandstones giving them a limited reservoir quality. The Neogene (1.6-23.7 Ma) volcanic and sedimentary rocks of the Masset and Skonun formations (respectively) unconformably overly the Paleogene and older successions. The marine and terrestrial Masset Fm is comprised of up to 4,000 m, basalts, rhyolite flows, and pyroclastics. These represent good reservoir rocks. The Skonun consists of interbedded sandstone, shale, conglomerate and lignite (coal), up to 6 km thickness offshore. This contains the primary petroleum exploration targets, with sandstone porosities between 25 to 35% (>2000m), and fair to very good permeability (10 to 1500md) (Dietrich, 1995). At depths of 2000-3000m porosity decreases by 5%, with fair permeability (10 to 100md). Below 3000m, reservoir potential is minimal due to low permeability.

Basic Structural Framework

The QCB is within the tectonic province called the Insular Belt. As noted, the basement of this Tertiary extensional syn- and post-rift type basin is the Wrangellia supracrustal terrane. The main structural features within the Queen Charlotte Basin developed in association with Miocene transtensional and Plio-Pleistocene transpressional tectonics.

The QCB is characterized by 4 Paleozoic - Cenozoic tectonostratigraphic divisions, namely:

1. Permian - mid Jurassic,
2. Mid - Late Jurassic
3. Cretaceous
4. Tertiary

The L. Triassic/E. Jurassic (Karmutsen Fm, Kunga Gp, Maude Gp) are comprised of intraoceanic and island/back-arc rocks of Wrangellia Terrane. These are typical of a back-arc rifting, allochthonous to N. America plate. The Mid/L. Jurassic (Yakoun Gp and Moresby Gp) contain the San Christoval and Burnaby Island Plutonic Suites. The structural components are discrete NW dip-slip faults with uplifted tectonic blocks. The Cretaceous (Longarm Fm and Queen Charlotte Gp) can be characterized by block faulting and relatively long wavelength NW-trending folds (□ ca. 0.5 - 1.5 km).

The Tertiary (Paleogene, Masset Fm and Skonun Fm) structural unit has active steep NW, N and ENE faults (sinistral strike-slip). The extensively fault-controlled basin development has created a complex assemblage of graben and half-graben fills highly variable in thickness and with compressional inversions and deformation (Rohr and Dietrich, 1992). Miocene structures include north and northwest aligned normal and oblique slip faults. Pliocene structures include reverse faults (often a result of inversions of Miocene normal faults), contractional folds and combination fault-fold flower structures. Pleistocene structures are local folds and tilted, truncated Neogene strata. In relation to structures forming potential traps for petroleum accumulation, Table 1 shows the variety of both structural and stratigraphic traps that may occur within the basin. It is important to note that Pliocene traps are restricted to northern Hecate Strait and Dixon Entrance. Stratigraphic traps may also be locally present in shallow parts of the Queen Charlotte Basin where tilted Neogene strata are unconformably overlain by Quaternary mudstones.

Table 4. Paleozoic - Cenozoic Tectonostratigraphic Divisions

L. Triassic/E. Jurassic

- Karmutsen Fm, Kunga Gp, Maude Gp
  - intraoceanic and island/back-arc rocks of Wrangellia Terrane
  - back-arc rifting, allochthonous to N. Am plate.

Mid/L. Jurassic

- Yakoun Gp and Moresby Gp
  - San Christoval and Burnaby Island Plutonic Suites
  - discrete NW dip-slip faults with uplifted tectonic blocks

Cretaceous

- Longarm Fm and Queen Charlotte Gp
  - block faulting, NW folds (□ ca. 0.5 - 1.5 km)

Tertiary

- Paleogene, Masset Fm and Skonun Fm
  - active steep NW, N and ENE faults (sinistral strike-slip)
  - fault controlled basin development (graben and half-graben fills)
  - compressional inversions and deformation

Source Rock Potential

The offshore deepest wells in the Hecate Strait of the Queen Charlotte Basin have penetrated only the uppermost Cretaceous, so the deeper source rock information is speculative. Basically, the source rocks in the QCB are either older oil prone Type I/II kerogens or younger gas prone Type III kerogens.

Source rock distribution is considered to be highly irregular due to episodic erosion events from Middle Jurassic through Tertiary time. Kunga-Maude strata are most likely preserved in the southwestern part of the basin beneath Graham Island and western parts of Dixon Entrance, Hecate Strait and Queen Charlotte Sound (Thompson et al., 1991; Lyatsky and Haggart, 1993). Upper Kunga limestones and argillites and lower Maude shales contain oil source rocks with Type I and Type II organic matter. Total Organic Carbon (TOC) averages 1 to 4 wt % in sections up to several hundred meters thick. If Late Jurassic through Tertiary block faulting occurred offshore as well as onshore, erosion could have potentially removed source strata from some areas, especially adjacent to the eastern side of Southern Moresby Island (Thompson et al., 1991). In some offshore areas, carbonaceous beds and coal seams in non-marine Upper Cretaceous strata may have some gas potential. Skonun formation strata contain coal beds and dispersed type III organic matter (Figure 3). Organic content ranges from 0.5 to 1.5 wt % with higher TOC (up to 25%) in coal beds. Skonun shales and siltstones locally contain type II organic matter with up to 2.5% TOC (Vellutini and Bustin, 1991). Coal beds are more abundant in the northern half of the Queen Charlotte Basin.

Kunga-Maude rocks are overmature on the southwestern Queen Charlotte Islands, and marginally mature to mature on central and northern parts of the islands. Maturation of Kunga-Maude strata in offshore areas is unknown, but is expected to vary from mature to overmature. Model predicted profiles for the two Sockeye wells (B-10, E-66) indicate that these strata will be overmature at B-10 and mature to overmature at E-66. For the Sockeye area and many parts of central Hecate Strait most source rocks will be within oil window at depths above 3000m. Neogene strata are immature to mature with 30-40% of total basin fill falling within the oil or gas generation window. Depth to the top of the oil window typically occurs at 2000-2500m. Onshore, Macauley (1983) showed Kunga-Maude sediments that are within oil-generating phase in the Ghost Creek-Rennell Junction areas of the Skidegate Plateau, but are overmature westerly at Shields Bay and southerly at Maude Island, both along the easterly front of the Queen Charlotte Ranges.

Oil shale potential is limited to the Ghost Creek area. Both Kunga and Maude formations have generated oil, and hydrocarbon yields from organic-rich beds in the central Queen Charlotte Islands are up to 50 to 100mg HC/g rock, with excellent oil source capability. These strata are a potential source for oil accumulations below the Tertiary Masset volcanics in the Charlotte lowlands of northeastern Graham Island and under Hecate Strait.

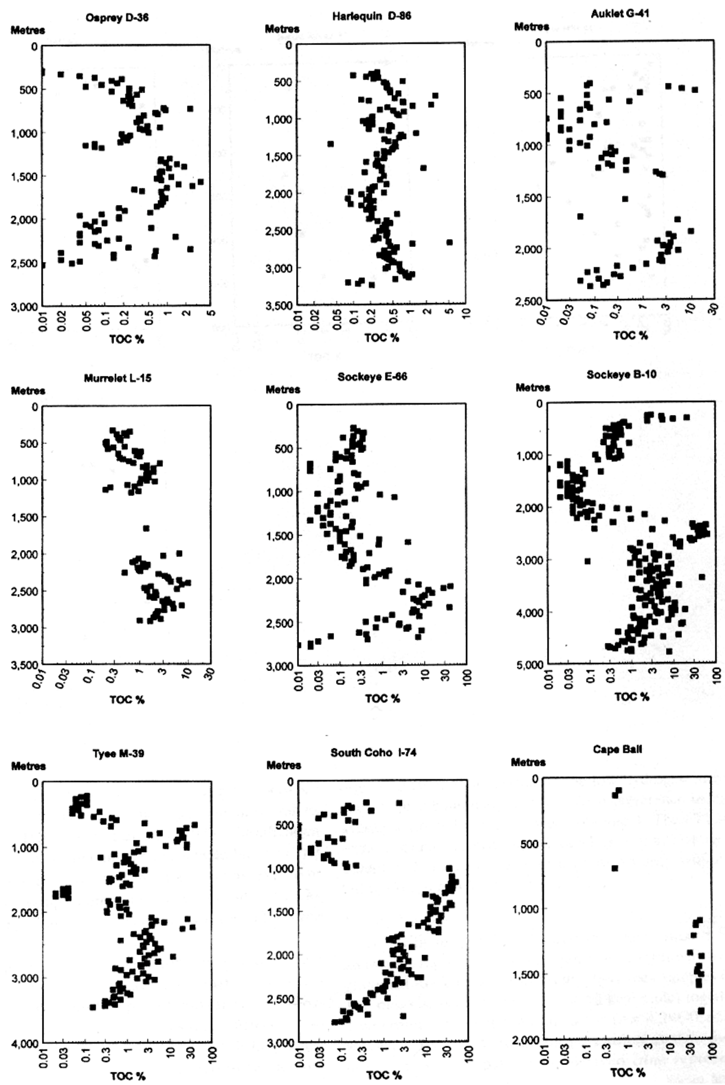


Figure 3. Total Organic Carbon (wt % TOC) depth distributions in QCB wells (from Bustin, 1997).

Bustin (1997) analyzed TOC in offshore wells drilled by Shell Canada in the late 1960’s, and found variations with depth that compliment a biparite stratigraphy developed by Higgs (1991) (Figure 3). Unit 1 is comprised mainly of middle Eocene to middle/late Miocene age syn-rift deposits, greater than 5km in thickness (mostly Skonun Fm). Unit 1 includes marine and non-marine clastics (sandstone, mudstone, coal and pebble conglomerates) and volcanics in predominantly northwest and less commonly east or northeast trending grabens and half-grabens. This unit is draped by marine and non-marine post-rift strata up to 2 km in thickness of early Miocene to Quaternary age sediments termed Unit 2. The base of Unit 2 was chosen to distinguish a distinct change in log character, whereby most logs become erratic due to the presence of coal interbeds.

TOC showed a systematic “S shaped” variation in six wells (D-36, G-41, B-10, E-66, N-39, I-74) ranging from 0.5 wt. per cent at the base of Unit 1 to almost 30 per cent near the contact of Unit 1 and 2 (Figure 3). Bustin (1997) attributed this with a shift from predominantly non-marine strata of Unit 1 to transitional marine–non-marine strata of Unit 2. TOC declines to 0.5 per cent in the middle of Unit 2, only to increase back to 30 per cent in all wells except E-66 near the surface. The N-39 and D-36 wells show a decline in TOC towards the surface. Other wells (D-86 and L-15) showed no clear trend for TOC. The increase to the top of Unit 2 and the lack thereof in other wells was interpreted as either a decrease in clastic sedimentation rate (hence dilution of organic matter), or a progressive decrease in transitional marine and increase in non-marine strata. Bustin (1997) noted that neither well logs nor biostratigraphy could definitively resolve the trends observed in TOC content. Kerogen types are mostly type III, with exception of B-10 having some type II. There is poor correlation between TOC and hydrogen index (HI) values. No stratigraphic trend for TOC or HI was evident in any onshore wells examined, most likely due to limited data.

Bustin (1997) also noted that an increase in the pristane/phytane ratio with depth in some wells can be interpreted as a greater abundance of terrestrially derived organic matter. The abundance of organic matter and to a lesser degree source rock quality closely follows the biparite stratigraphy in the offshore wells. Depth to the top of the oil window (Figure 3) follows the gross stratigraphy (Unit 1) more closely than depth of burial of the strata, from only 500m on Graham Island to more than 3000m in Queen Charlotte Sound (Tyee and South Coho excepted). Depth to the base of the window and thickness of strata in the window is strongly controlled by maturation gradients and paleoheat flows (i.e. steeper the gradient, less strata within the window). Tyee N-39 and Sockeye E-66 contain the thickest successions within the oil window. Basin modeling using a modified McKenzie model shows timing of peak hydrocarbon generation is also highly variable in offshore wells. Unit 1 in South Coho has yet to reach peak generation, while Sockeye wells passed this stage 20 my ago. In most wells (B-10, E-66, L-15, G-41, D-36) the base of Unit 1 reached an oil generative stage between 9 and 16 Ma. The base of Unit 2 has not reached oil generation phase in D-86, M-36 and I-74, but in other offshore wells this occurred between 7 and 20 Ma and currently remains in the oil window.

Table 5. Summary of Source Rocks in the Queen Charlotte Basin

1. L. Triassic/E. Jurassic Source Rocks
    - Kunga Gp: ca. 600 m
        - shallow to deep marine, limestones to siltstones, argillite, tuff
    - Maude Gp: ca. 300 m
        - deep marine, shale to siltstones, sandstones with mudstones
        - good late/over-mature oil and gas prone (Type I/II) source rocks
        - only information from onshore outcrop and shallow drill
2. Cretaceous Source Rocks
    - Longarm Fm and Queen Charlotte Gp
        - sandstones, shales, conglomerates, mudstones, volcanics
        - minor coal-bearing, non-marine intersections reported at base of Tyee, Sockeye B-10, E-66 wells.
        - very marginal, late/over-mature gas prone (Type III) source rocks
        - limited offshore and onshore outcrop and shallow drill information
3. Tertiary Source Rocks
    - Paleogene - basalts, andesites, conglomerates, black shale, sandstones
        - very marginal, mature source rocks
    - Masset Fm: up to 4,000 m, basalts, rhyolite flows, pyroclastics
        - very marginal, mature gas prone (Type III) source rocks
    - Skonun Fm: ca. 5,000 m - sandstones, shale, conglomerates, lignite
        - marginal-good, mature-late mature, gas prone Type III source rocks

Oil Shows and Seepages

Over 50 oil, tar, or natural gas seeps have been identified onshore Queen Charlotte Islands (Hamilton and Cameron, 1989) (Figure 4). Geological and geochemical analysis show seeps are migrated oils sourced from Kunga-Maude (Jurassic) and Tertiary strata (Fowler et al., 1987, Hamilton and Cameron, 1989). Seeps are widespread and exposed in roadcuts, quarries and beach outcrops, with bitumen and tar as the main products. Lawn Hill on the southeast coast of Graham Island contains one of the most areally extensive surface oil seeps, probably sourced from underlying or subadjacent Jurassic source rocks, with migration into host rocks in late Neogene time (Snowdon et al, 1988; Hamilton and Cameron, 1989). Cretaceous or Neogene reservoir strata in the surrounding or basinward areas is considered highly prospective for conventional oil accumulations. Shows at King Creek include oil staining, lighter oils, natural gas seeps and volatile petroleum hydrocarbons. Tar occurs in fractures and vesicles within thin basalt flows and agglomerates. Most shows are in Masset volcanics. King Creek shows suggested that a principal hydrocarbon source lies below a basal Tertiary unconformity in subjacent

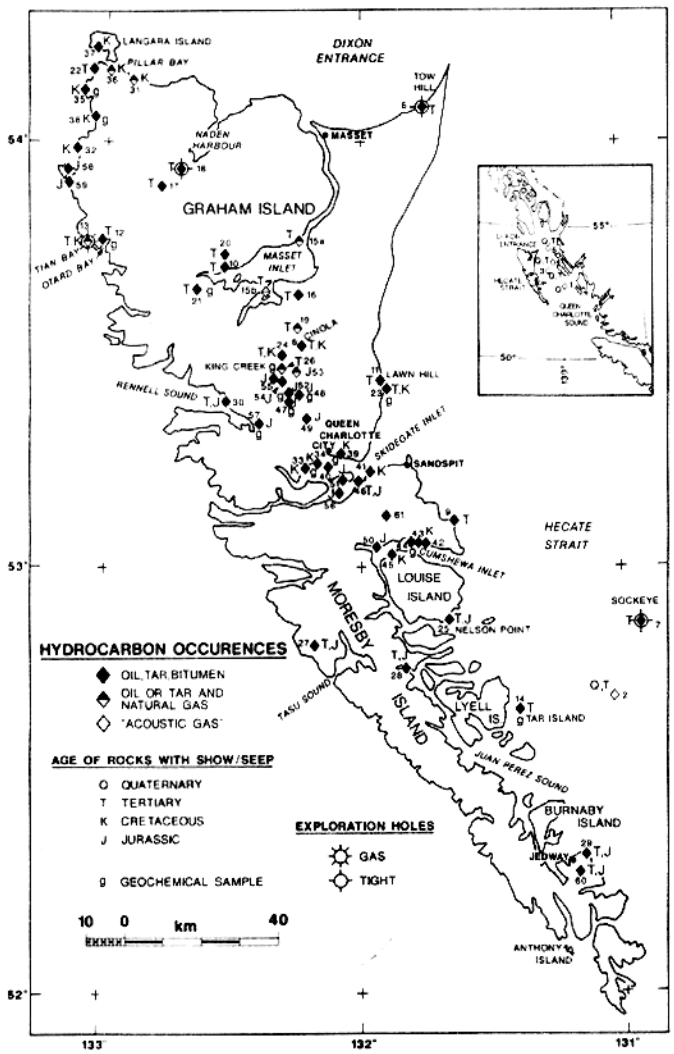


Figure 4. Location of observed hydrocarbon seepages on Queen Charlotte Islands (from Hamilton and Cameron, 1989)

Lower Jurassic rocks (Kunga-Maude). Hydrocarbons occur in primary and secondary porosity of the Masset formation from Otard Point to the head of Otard Bay. Oil films are common on streams and pools that drain this area.

Subsurface shows were encountered in several wells, most notably oil staining in Neogene sandstones of the Tow Hill (onshore) and Sockeye B-10 (offshore) wells (Hannigan et al., 1998). Biomarker analysis of the saturate fraction from the Sockeye sample indicated a compound diagnostic of a Kunga source rock, as indicated in similar analyses of Kunga outcrop samples. Other geochemical characteristics of the Sockeye sample also indicated a probable derivation from carbonate rocks. The Sockeye B-10 well also had numerous shows of gas-cut mud in coal-bearing zones in Skonun and Cretaceous strata below 3000m.

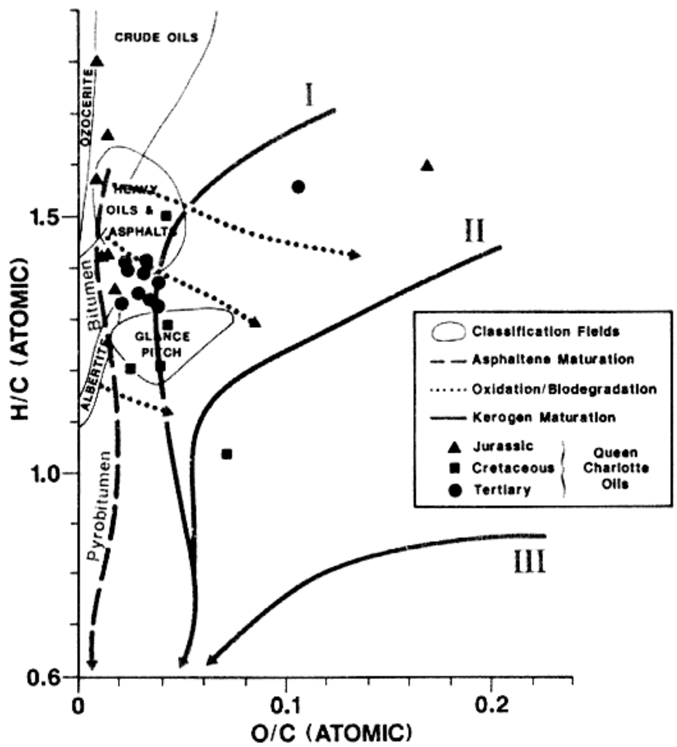


Figure 5. Bulk chemical composition of hydrocarbons recovered from seepages (from Hamilton and Cameron, 1989)

Hamilton and Cameron (1989) plotted oil show samples on a Van Krevelen diagram (Figure 5). Samples tended to group according to age. Oils did not appear to be intensely weathered. Jurassic oils had the highest H/C ratios and appeared to be the least migrated, lightest, and least viscous. Two models attempted to explain the compositional variations of these oils. Mixing models combined mature Jurassic with degraded Cretaceous source material, as Tertiary showings implied contributions from both type II (Jurassic) and type III (Cretaceous) sources. Many of the Queen Charlotte oils showed high sulfur content, indicative of a marine carbonate source (Kunga-Maude). GC analysis of King Creek and Lawn Hill oils showed low concentrations of n-alkanes below C_{20}. GC/MS data of several oils supported the concept of a dominant Lower Jurassic Type II source in Kunga-Maude strata. Variations in kerogen character complicated biomarker patterns. Trace metal abundance patterns for these oils resembled those from clastic assemblages with NaCl dominated formation waters.

Gas Shows and Seepages

Shallow gas deposits in the Queen Charlotte Basin can arise from two sources, either during early diagenesis from biogenic degradation of organic matter, or thermogenic gas diffusing upward from Tertiary bedrock. They are distributed over most of Hecate Strait and occur in most types of surficial sediments except where glacial till is at the surface

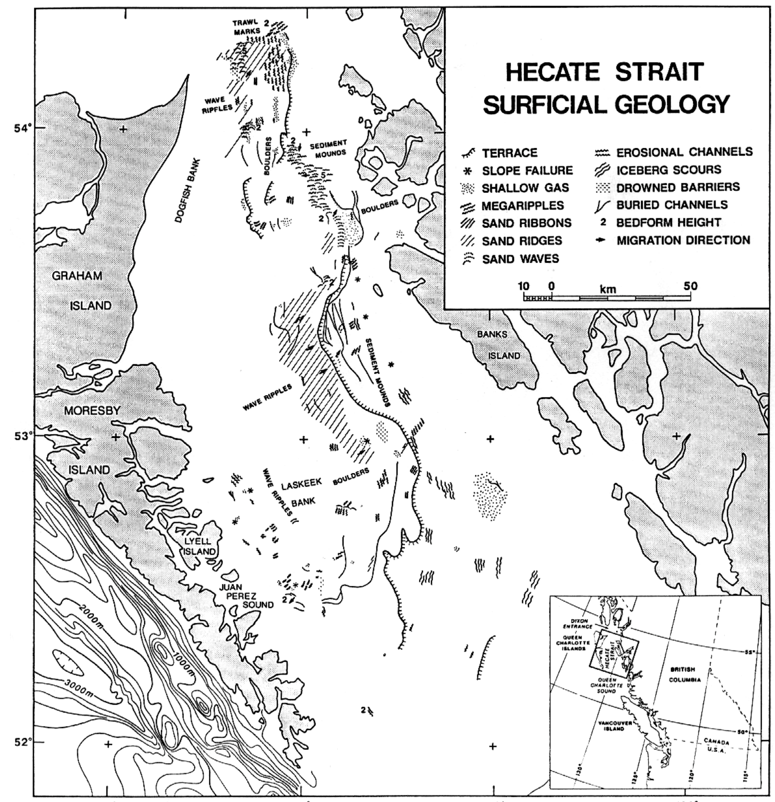


Figure 6. Surficial Geology of Hecate Strait showing surface gas locations (from Barrie, 1988)

(Barrie, 1988). Thick Holocene age silt deposits contain extensive amounts of biogenic gas. Gaseous sediments are also found along the base of underwater terraces, including the northern portion of the main trough and within the northern trough into Dixon Entrance (Figure 6). Sediments containing gas are generally near the contact of glacial till with a sand and gravel unit (Unit 3 of Barrie, 1988) and gas appears to migrate along the boundary. Gas charged sediments are also present on the western side of Hecate Strait in Unit 3 sands and areas where sands thinly cover Tertiary bedrock. Gas shows along the axis of Hecate Strait mark the western edge of a cordilleran till lobe, inferring that the till forms a cap structure (Hamilton and Cameron, 1989). Acoustic gas may indicate overmature source rocks or a different subsurface geology (gas prone). Figure 26 of Barrie (1988) shows sediment instability due to gas accumulation and a potential drilling site. Deep gas accumulations in Neogene strata have been identified on conventional seismic profiles in several offshore locations (Dietrich, 1995). An example of a direct hydrocarbon indicator is a subhorizontal low frequency at the crest of a fault bound structure. Dietrich (1995) added that several of these indicators occur at a stratigraphic level similar to the Sockeye B-10 well show.

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Appendix 7: Comparison of Queen Charlotte Basin Petroleum Situation with Other Offshore Basins[5]

1. COOK INLET (ALASKA)

The following information is extracted and reworked in part from Magoon, (1994) and Thompson et al. (1991).

Overview

Geographically, Cook Inlet on Alaska's southern coast is bordered to the northwest by the Alaska-Aleutian Range and Talkeetna Mountains, and the Kenai Peninsula-Kenai Mountains on the southeast (Figure 14). Discovery of the first field was in 1957 at Swanson River, and the subsequent history of petroleum exploration and geology in the area has been discussed by numerous studies (e.g., Magoon and Claypool, 1981; Magoon and Egbert, 1986; Magoon and Kirschner, 1990). Hydrocarbon production is from six oil fields (Trading Bay, McArthur River, Middle Ground, Granite Point, Beaver Creek, Swanson River) and three gas fields in upper Cook Inlet. Oil fields occur near the basin margin, where Tertiary reservoir rocks unconformably overlie Middle Jurassic source strata (Figure 22.3). Several accumulations are also in Oligocene-Miocene sandstones within thrust faulted Pliocene anticlines (similar to Queen Charlotte Basin).

Total petroleum resources (produced and remaining) in Cook Inlet are 2.2 Bbbl of oil and 10 Tcf of gas (Magoon and Kirschner, 1990). The largest accumulations are the McArthur River oil field (570 Mbbl) and the Kenai gas field (2.3. Tcf), both of comparable magnitude to largest fields predicted for Queen Charlotte Basin (Hannigan et al., 1998). Exploration is based on a two-part geological model of Magoon and Claypool (1981):

1) Burial and maturation of Jurassic source rocks occurred during Cretaceous and Early Tertiary, followed by updip migration of hydrocarbons into conglomerate and sandstone reservoirs of Oligocene age;
2) Hydrocarbons remobilized during Pliocene and Pleistocene deformation, filling new traps created in faulted anticlines and upturned stratigraphic pinchouts.

[5] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

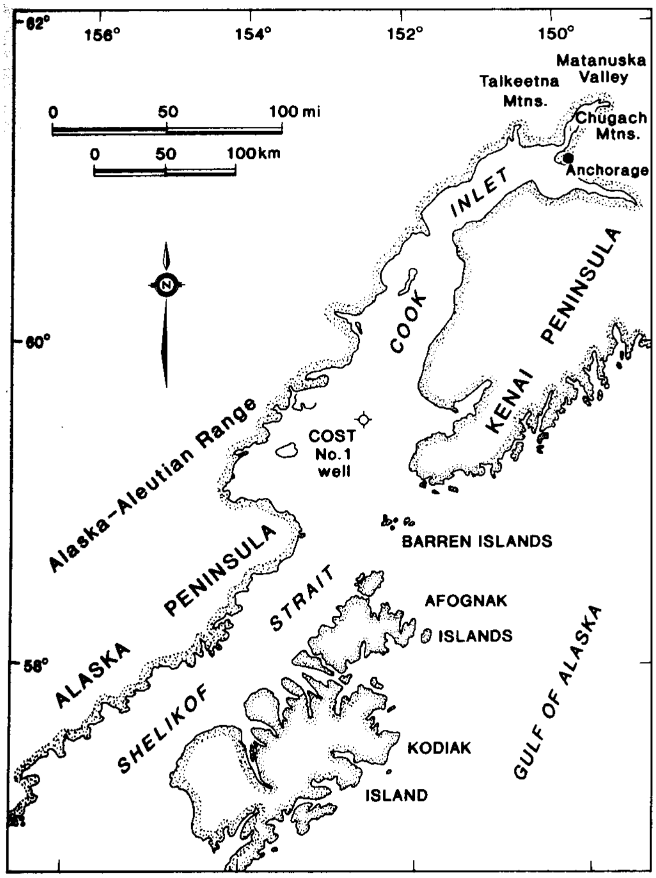

Figure 14: Geography of the Cook Inlet region, Alaska (modified from Magoon and Egbert, 1986, Fig. 32).

Figure 1. Location map of Cook Inlet, Alaska, (after Magoon and Egbert, 1986

Basin History and Stratigraphy

Cook Inlet evolved from a backarc basin setting during Mesozoic time to a forearc basin in the Cenozoic. During the Mesozoic, the Aleutian Range-Talkeetna Mountain magmatic arc was active producing mainly volcanic flows and volcaniclastic sediments, as well as sand, silt, and gravel all rich in feldspar and lithic fragments. Four sequential tectonic episodes are defined by unconformities separating clastic successions from Early Cretaceous to late Cenozoic. Cretaceous strata are mostly marine while Tertiary strata are predominantly nonmarine. Cross section (Figure 22.4) shows the generalized structural style with numerous high-angle reverse faults indicating considerable compression throughout the Mesozoic and Cenozoic with minor normal faults near the Swanson River field.

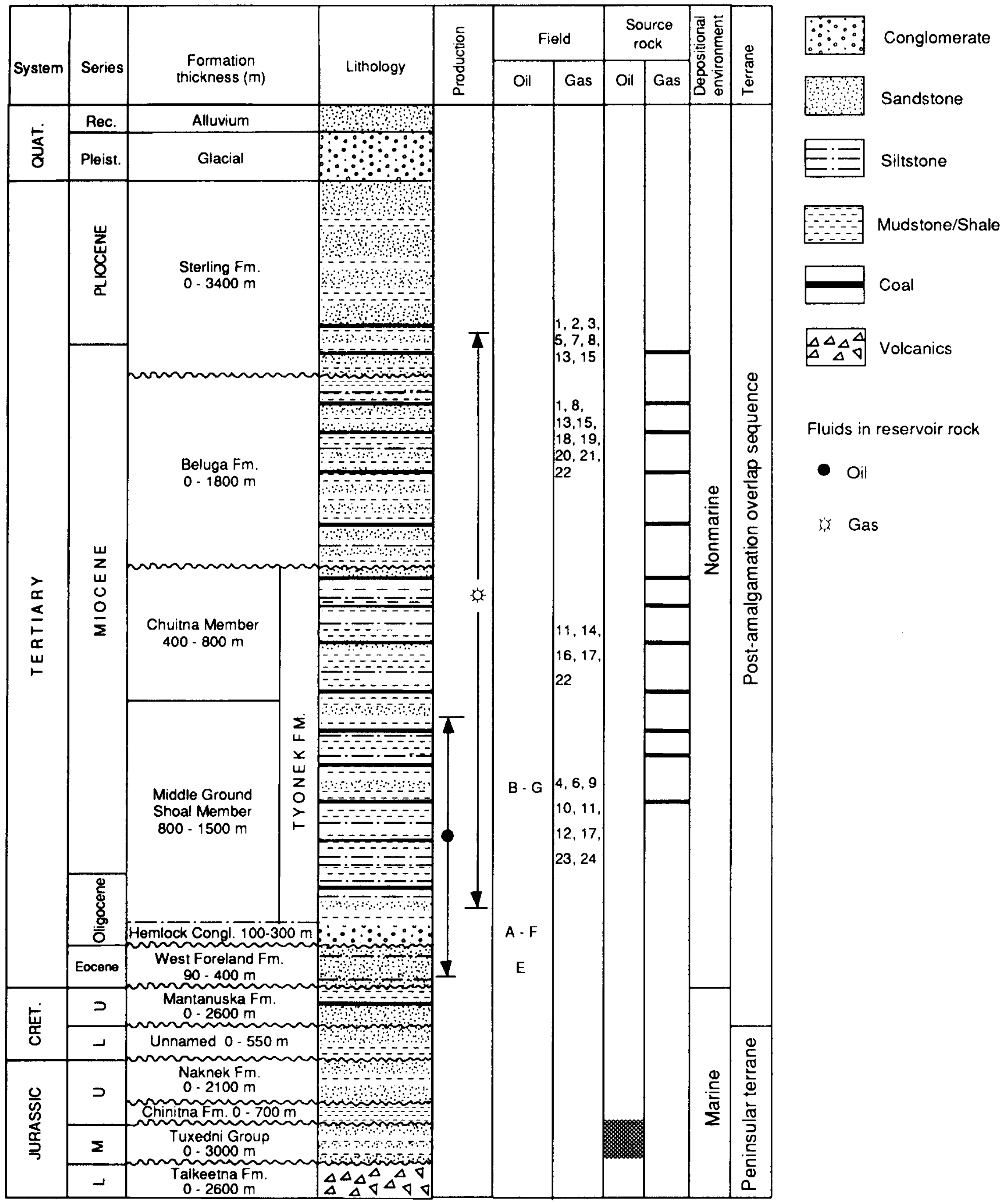

Figure 2. Statigraphic column for Cook Inlet (from Magoon, 1994)

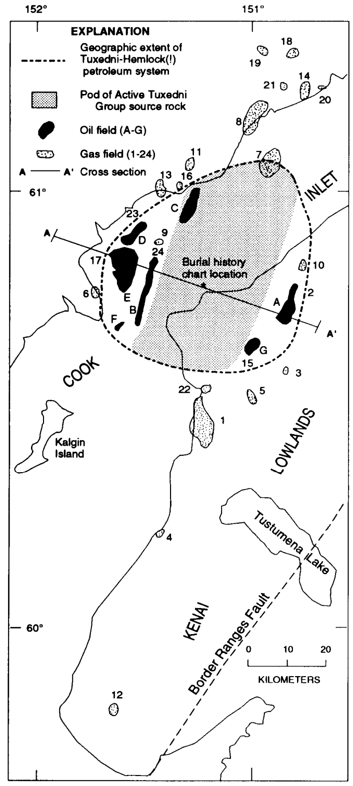

Figure 3 Cook Inlet oil and gas fields (from Magoon, 1994)

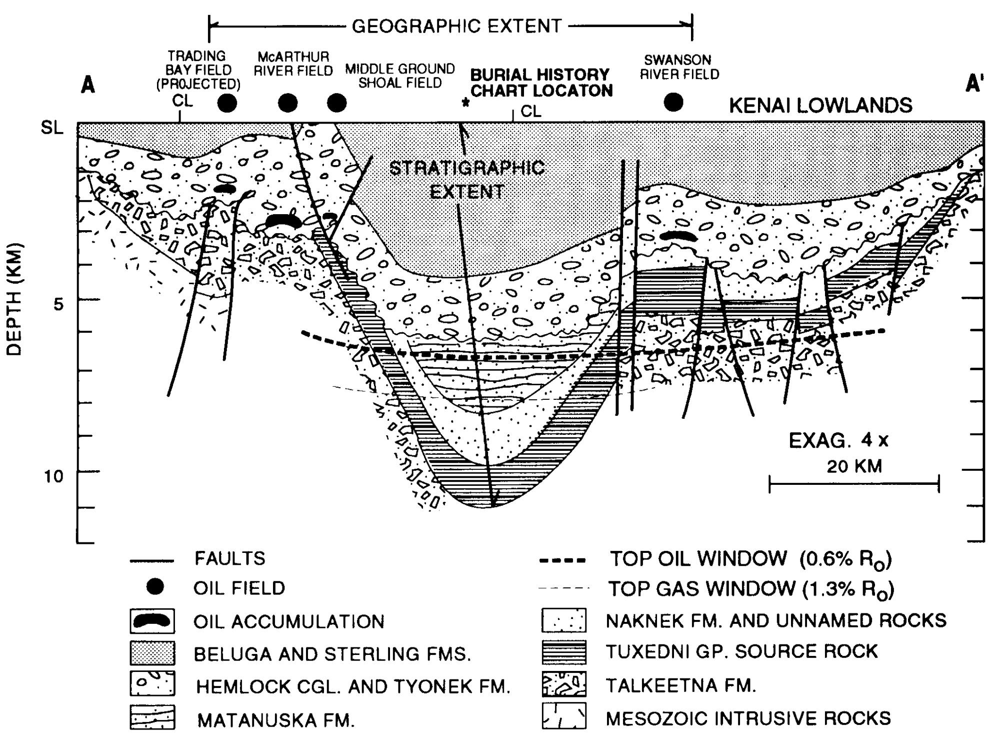

Figure 4 Geological cross section of Cook Inlet showing oil window maturity (from Magoon, 1994).

The Lower Jurassic Talkeetna Formation comprised of volcaniclastic sediments (along with the Alaska-Aleutian batholith) act as the economic basement for the petroleum province. The Tuxedni Group (dark gray, clay-rich siltstone) of Middle Jurassic age is important as the primary source rock for commercial oil deposits in the region. Upper Jurassic Naknek Formation contains a high percentage of feldspathic sandstone and conglomerate, but due to laumontite cementation is considered a poor reservoir (Bolm and McCulloh, 1986). An unconformity separates the Lower Cretaceous rocks from the Upper Cretaceous sequences, with the sandstone Matanuska and Kaguyak Formations containing little organic matter but do, in some places, act as a potential reservoir. Another unconformity separates Upper Cretaceous from Cenozoic strata. The West Foreland Formation consists of tuffaceous conglomerates to siltstones with minor amounts of coal. The Hemlock conglomerate is conglomeratic sandstone, with the Tyonek, Beluga, and Sterling formations comprised of varying amounts of sandstone, siltstone, shale and coal. Each of these rock units is a reservoir for oil or gas somewhere in the basin.

Petroleum System

The Tuxedni Group underlies most of Cook Inlet east of the Middle Ground Shoal oil field and subcrops in beneath Cenozoic strata east of Swanson River (Figure 22.4). Thickness is estimated at 1 km in the deepest part of the basin between the McArthur River and Swanson River fields. Thermal maturity of the source rock ranges from immature to mature, with TOC ranging from 2.1 wt% for immature samples to 0.9 wt% for mature samples. Based on basin modeling of Magoon (1994), the top of the oil window was reached during the Paleocene (63 Ma) and the gas window was achieved in the late Miocene (10 Ma).

Approximately 80% of recoverable oil is contained in the Hemlock Conglomerate, 20% in the Middle Ground Shoal member of the Tyonek Formation, and minor amounts in the West Foreland. Average porosity for conglomeratic sandstones is 17% (12-22%), with average permeability of 80 md (10-360 md). Seal rocks for most oil accumulations are presumed to be siltstones of the West Foreland and Tyonek Formations, and underclays associated with coals within the Tyonek Formation. Typical pools are located in faulted anticlines at average drill depths of 2560 m. A typical oil has an API gravity of 34 +/- 6 degrees, a gas-oil ratio (GOR) of 600 (175-3850), sulfur content of 0.1%.

Migration of oil is inferred based on cross sections and burial history models. Source rocks are currently within the gas window, although very little gas appears to have been generated (GOR <1000). Oil generated over the last 63 Ma has migrated updip to the flanks of the basin, and trapped stratigraphically until structural traps formed during Miocene deformation (10 Ma). Oil generated or migrated before deposition of the Hemlock Conglomerate (30 Ma) could have been lost to erosion. Based on a synclinal basin geometry, oil migrated laterally through sandstone within the source rock or in the overlying Naknek Formation to the Cretaceous-Tertiary unconformity, across the unconformity, through the West Foreland Formation and into the Hemlock Conglomerate.

A model similar to Cook Inlet may apply to the Queen Charlotte Basin. Thompson et al. (1991) noted that surface mapping showed some fault-bounded blocks have been stripped of Middle Jurassic strata, placing Triassic/Jurassic Kunga-Maude source rocks adjacent to potential Cretaceous reservoir strata. Applying this to offshore areas creates a scenario much like that in Cook Inlet, whereby source rocks are overlain unconformably by Lower Cretaceous and Tertiary sandstones (Figure 16). One could expect updip migration of hydrocarbons into overlying sandstones and possible secondary migration along the youngest set of Tertiary extension faults. Pliocene deformation in both basins has produced faulted anticlines which can constitute traps for oil and gas accumulation.

Similarities to Queen Charlotte Basin

- Basins evolved in intra-arc and forearc settings
- Jurassic source beds
- Cretaceous and Tertiary clastics for reservoir beds
- Major regional unconformities on top of Upper Jurassic/Lower Cretaceous and Upper Cretaceous sequences
- Variety of type and stratigraphic distribution of oil shows (e.g. seeps)

- Timing of oil generation and migration (late Tertiary, after burial of Jurassic source rocks beneath thick cover of Tertiary strata)
- Traps include faulted anticlines as a result of Pliocene deformation/compression

Hannigan et al. (1998) and Dietrich (1995) also note that Mist Lake gas field in the forearc Willamette Basin of northern Oregon occurs in Eocene sandstones with compositional and reservoir characteristics of Neogene sandstones in the Queen Charlotte Basin.

Differences to Queen Charlotte Basin

- Neogene tectonic/structural history. During Eocene, a regime of convergence accompanied by subduction gave way to northward transcurrent motion of oceanic plates along the continental margin replacing the forearc setting with a strike-slip margin in the Queen Charlotte region. Cook Inlet contains comparatively fewer strike-slip related extensional faults (Hannigan et al., 1998).
- Source rock distribution in Queen Charlotte Basin is more sporadic due to heating associated with Middle Jurassic plutonism and uplift and erosion of source strata during Late Jurassic and Cretaceous.
- Quality of seismic data for Queen Charlotte Basin is considered to be insufficient to assess the thickness, distribution, and structure of pre-Tertiary source and reservoir strata.

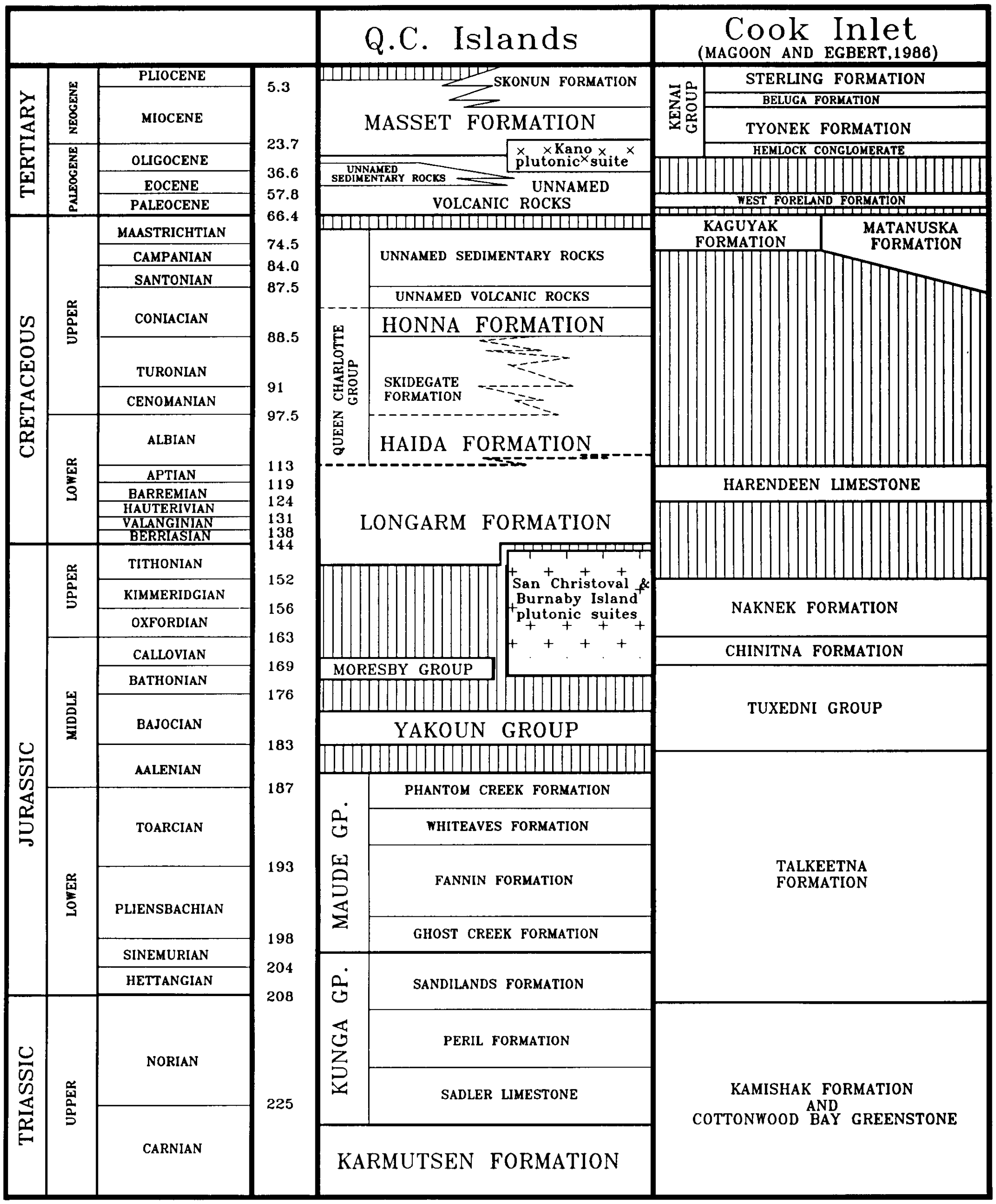

Figure 6. Comparison of geologic stratigraphic columns of Cook Inlet and Queen Charlotte Basin (after Magoon and Claypool, 1981 and Magoon and Egbert, 1986)

2. CALIFORNIA

Biostratigraphic studies indicate correlations with basins in southern California and northern Mexico (Hamilton and Cameron, 1989).

Petroleum geology of Great Valley and southern California continental borderland basins may provide useful comparisons based on similar age and tectonic setting (Hamilton and Cameron, 1989). The Queen Charlotte Basin has been compared to the borderland based on similar Neogene tectonic history and structural characteristics (Rohr and Dietrich, 1992). Several Neogene strike-slip basins occur in the California borderland region including the oil rich Los Angeles Basin estimated at 10 Bbbl (Biddle, 1992). The primary difference between the basins is type of source rocks, thereby limiting comparison of petroleum yield estimates. However, strike-slip basins are considered to be above average in terms of hydrocarbon potential.

3. EAST COAST

Hannigan et al. (1998) note that no direct analogues can be drawn between the Queen Charlotte Basin and other Canadian oil provinces. In ranking median recoverable resource estimates, the Queen Charlotte Basin with 2.6 Bbbl of oil and 20 Tcf of gas has a gas endowment comparable to the Scotian Shelf (18 Tcf, Wade et al, 1989) and oil reserves of about half those in the Jeanne D'Arc Basin (4.7 Bbbl, Sinclair et al., 1992). The Jeanne D'Arc also contains an estimated 13 Tcf of gas along with 1 Bbbl of oil for the Scotian Shelf. All these basins are overshadowed by a potential 7 Bbbl of oil and 68 Tcf of gas proposed for Beaufort-MacKenzie Basin in the Canadian Arctic (Dixon et al, 1994).

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Appendix 8: Faulting and Seismicity in Queen Charlotte Basin[6]

Seismicity is a potential hazard in the Queen Charlotte Basin. Earthquakes from the nearby plate boundary, the Queen Charlotte Fault, can be as large as M=8.1 (Fig. 1) and magnitude 6 events are common on the Revere-Dellwood Fault to the south. These events can cause considerable shaking in the adjacent plate margin. Small earthquakes occur frequently in the Queen Charlotte Basin itself (Bird, 1997), but appear to be concentrated in northern Hecate Strait. This can be explained as a part of the transpressional deformation occurring across the plate boundary in the last 5 Ma (Rohr et al., 2000).

Assessments of seismicity include modern records of earthquake activity but also geophysical and geologic knowledge of structures and evidence of recent movement on faults. Electronic records of seismicity are most useful but, unfortunately, are restricted in time and place. The geologic record can show the longer term results of activity. Commonly sought evidence of recent activity is a fault cutting the ground or seafloor. However, many factors can work to overprint such a signature and inactive ancient faults exposed at ground level may have topographic offset simply because of erosion. Blind thrusts may not cut the surface yet shaking from earthquakes on them can be quite destructive (S.C.E.C., 1994).

Side-scan, high resolution seismic reflection (Barrie et al, 1990) and multi-channel seismic reflection data (Rohr and Dietrich, 1992) have been examined (Appendix) in the regions of earthquake activity in the Queen Charlotte Basin determined by Bird (1997) (Fig. 2). Broad anticlines cut by vertical faults and networks of smaller branching faults are observed in northern Hecate Strait (Fig. 3). The structures are consistent with focal mechanisms dominated by strike-slip and thrust events (Bird, 1997) with the occasional extensional event, as in any transpressional environment. Structure in the Tertiary sediments within 100-200 m of the seafloor was not imaged by existing seismic reflection data; data to map this area should be collected.

Earthquake location programs used by Bird assumed that the upper crust has a uniform velocity of 5.8 km/s and ignored the presence of lower velocity sediments so one can not incontrovertibly place an earthquake on a known fault. The co-existence of seismicity and significant deformation of both sediments and basement in Hecate Strait is surely not fortuitous. These structures should be considered capable of motion.

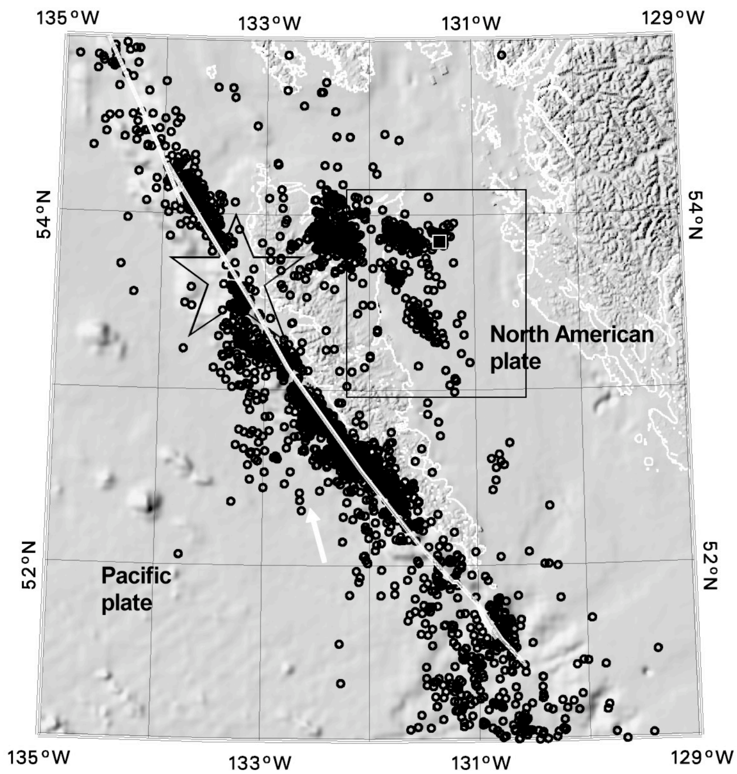

Figure 1. Microseismicity from Bird (1997) plotted on bathymetry; each event is shown as a single uniform-sized circle. Queen Charlotte Fault (white line) is the plate boundary between the Pacific and North American plates; the arrow indicates relative plate motion. Magnitude 8.1 event is shown as a star; magnitude 5.3 event is shown as a small white box. Large black box encloses area of Figure 2.

[6] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Kristin M. M. Rohr. December 2001.

Other faulted folds in the region have been mapped (Rohr and Dietrich, 1992), but are not currently associated with seismic activity. Detailed information for micro-earthquakes is best for the period of 1982 to 1996 when extra stations were placed in the region (Bird, 1997). Whether that 14-year time slice is representative of the last 100 years and can be reliably used to predict the next 10 to 50 years of seismicity is unknown. Rohr et al. (2000) make arguments based on the geologic, morphologic and paleomagnetic data of the Queen Charlotte Islands that deformation has proceeded from south to north in the last few Ma; one could reasonably expect seismic activity to remain concentrated in the north. This does not, however, preclude the possibility of earthquakes occurring elsewhere in the weak and regionally stressed crust underlying the Queen Charlotte Basin.

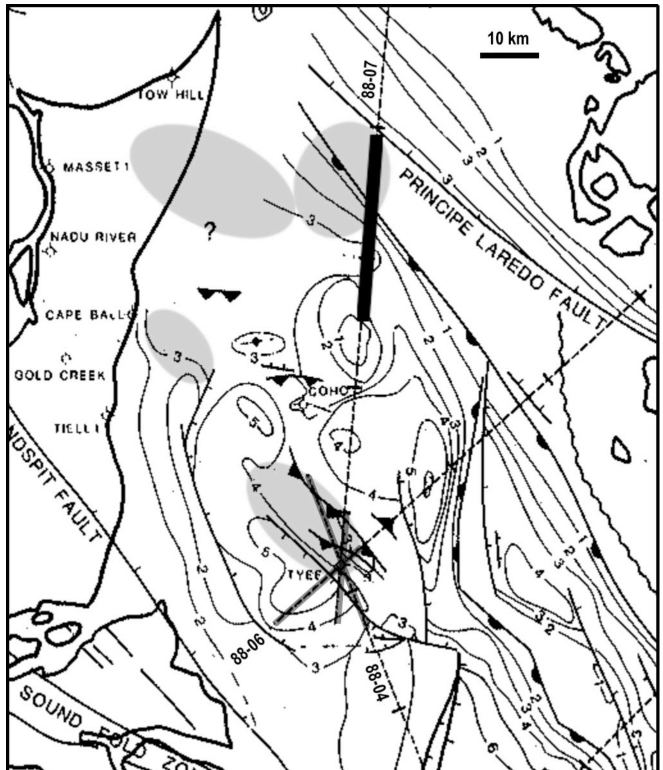

Figure 2. Sediment thickness map for northern Hecate Strait (after Rohr and Dietrich, 1992). Dashed lines are multi-channel seismic reflection profiles collected in 1988. Grey ellipses enclose clusters of microearthquakes identified by Bird (1997). The northern cluster (near the Principe Laredo Fault) includes the M=5.3 event in 1990 and its aftershocks. The portion of line 88-07overlying this cluster is shown in Figure 3.

Tectonically and structurally the Queen Charlotte Basin is similar to the Miocene Basins in California which are rich sources of petroleum production. Producing wells occur both on land and offshore. Both regions experienced Miocene extension followed by Pliocene compression and are near transform plate boundaries. Other areas with both production and proximity to transform plate boundaries include Indonesia and New Zealand.

Ground motion calculations by the Geological Survey of Canada in the Queen Charlotte Basin indicate that a large structure roughly ten-stories tall has a 10% chance of experiencing movement of 0.16 to over 0.32 m/s in a 50-year period from seismic waves with a frequency of 1 Hz. A smaller building has a 10% chance of experiencing an acceleration of 0.11 to over 0.32 g in a 50 year period from seismic waves with a frequency of 5 Hz. The greatest risk is from large events on the plate boundaries. Differences in structure between oil rigs and office buildings as well as local substrate should be taken into account when assessing hazards due to seismicity in Queen Charlotte Basin. Areas of southern California producing oil have a 10% chance of experiencing an acceleration of 0.1 to over 0.6 g in a 50 year period.

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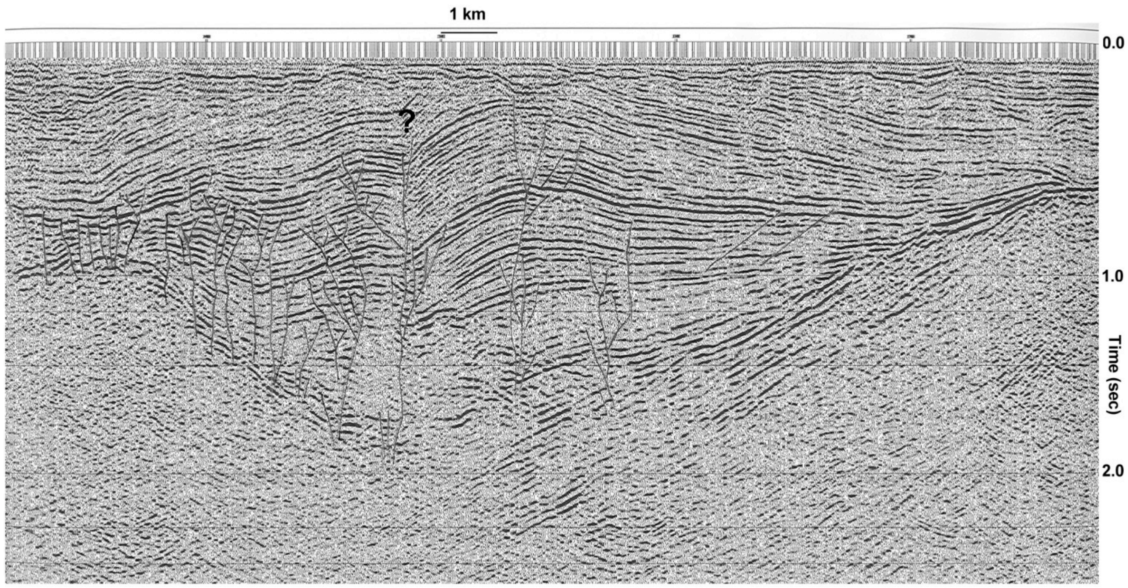


Figure 3. Migrated section of line 88-07. This sub-basin occurs south of a seismically active area in northern Hecate Strait.

Appendix 9: California – An Analogue to Queen Charlotte Basin?[7]

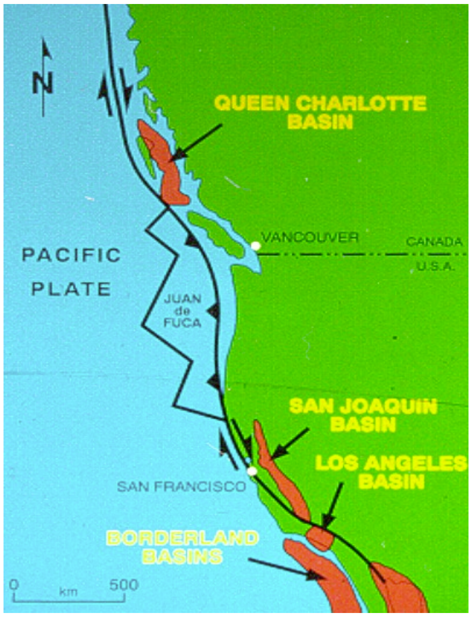


Figure 1. Cartoon of Pacific and North American plate boundaries.

Tectonically both the Queen Charlotte region and California are dominated by a transform plate boundary between the Pacific and North American plates (Fig. 1). In California the plates are moving at a relative rate of 40 km/Ma which is mainly carried by the San Andreas Fault, but also by a number of secondary faults (Fig. 2). Off British Columbia the rate is 48 km/Ma and is almost entirely carried by the Queen Charlotte Fault west of the Islands.

Geometry of the plate boundary in California has changed dramatically as two triple junctions migrated along the coast; the main transform fault has progressively moved inland over the years. The geometry of the Queen Charlotte Fault seems to have been fairly stable over tens of millions of years; triple junction complications have mostly been accommodated in oceanic crust to the south.

Both regions experienced extension in the Miocene followed by basin inversion and compression in the Pliocene. Small changes in the relative plate motion can explain the Pliocene compression but not the Miocene extension.

Hundreds of scientists have been detailing California's geology and tectonics since the 1800's. Many current studies are aimed at understanding seismicity including measuring the strain partitioning along the different faults in California in order to delineate potential hazards (Fig. 3). Over 700 hundred seismometers monitor every temblor; in some areas events can be mapped with accuracy of meters resulting in new insights into how faults behave. In contrast the Queen Charlotte region has only 9 permanent seismograph stations; the depth distribution of earthquakes on the Queen Charlotte Fault is entirely unknown. Stations lie east of the Fault and do not provide a good geometry to determine depth. Earthquakes on the shelf occur to depths of 15-20 km (Bird, 1997).

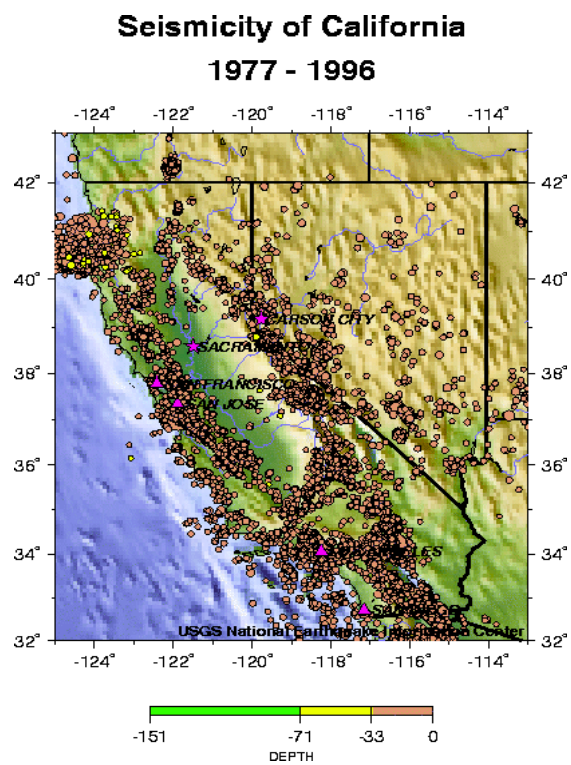
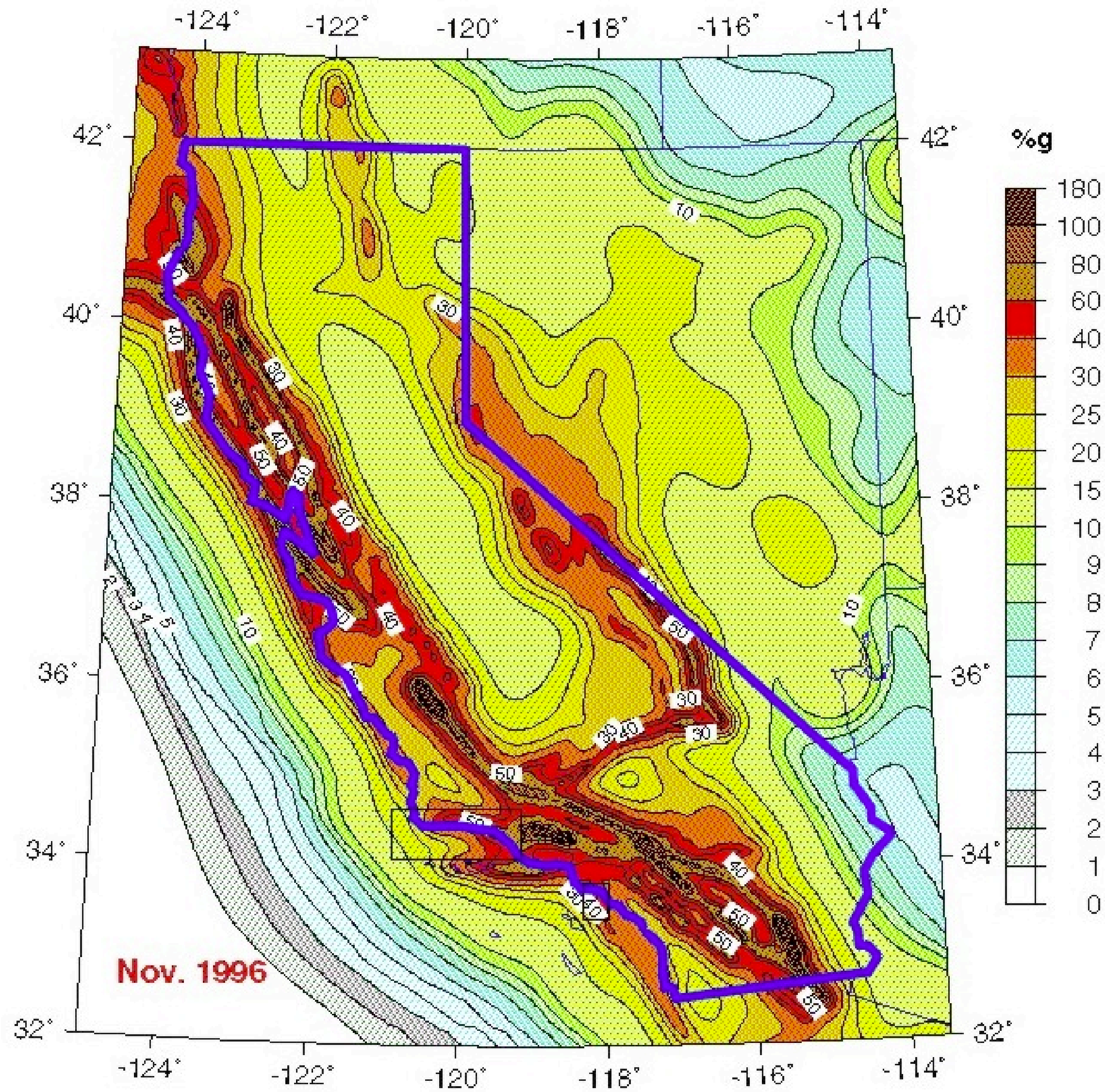


Figure 2. Seismicity is distributed along many faults in California.

7 Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Kristin M. M. Rohr. December 2001.

Peak Acceleration (%g) with 10% Probability of Exceedance in 50 Years
site: NEHRP B-C boundary



For California portion: U.S. Geological Survey - California Divison of Mines and Geology
For Nevada and surrounding states: USGS

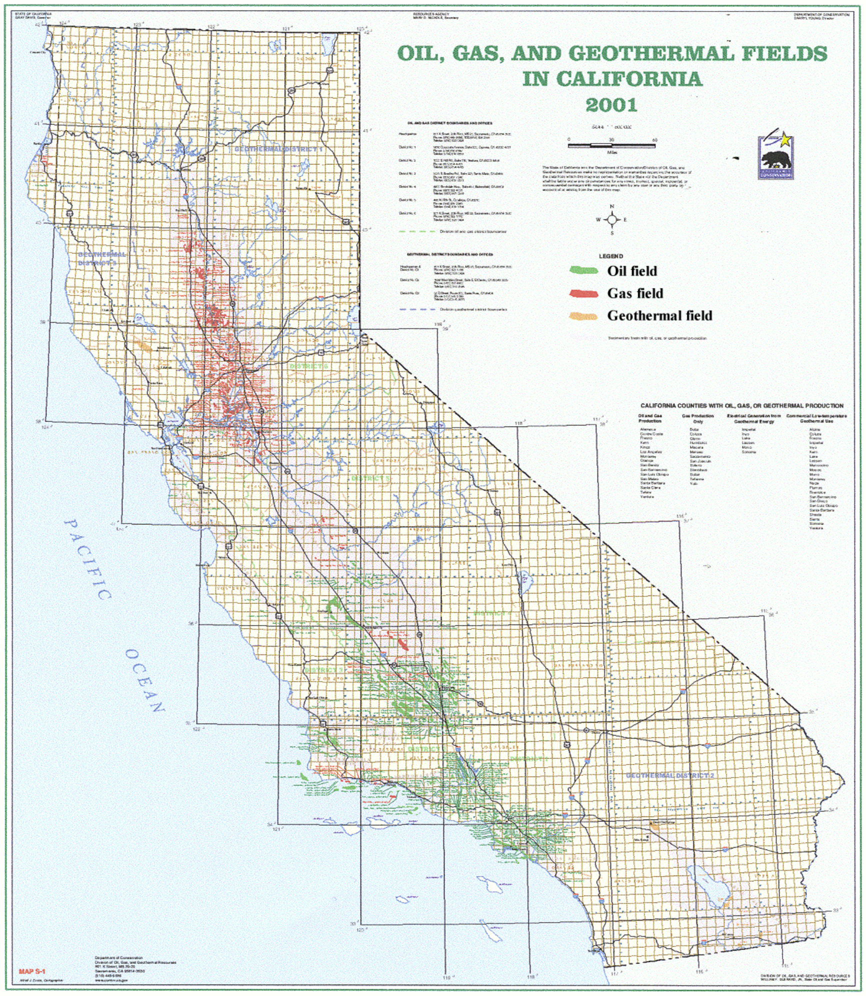


Figure 4. Oil, gas and geothermal fields in California, 2001, from California Division of Oil, Gas, and Geothermal Resources.

Seismicity and Oil and Gas Production in CA

California has a long and rich history of utilizing and producing oil and gas. In the 1500's natives were using asphaltum from ground seeps to seal containers; Europeans learned to caulk boats with it. The first commercial well began production in 1876; production has varied since then, but reached a peak in 1985 at 423.9 barrels of oil. Oil wells tend to be in southern California and purely gas wells in northern California (Fig. 4). In 2000 46,799 oil wells and 1,169 gas wells were producing hydrocarbons from 288 fields (Fig. 4); total production was 307.4 million barrels of oil and 379.1 billion cubic feet of gas. 1,412 offshore wells accounted for 17.6% of the total oil production and are largely found off southern California in a seismically active region. Areas within 3 miles offshore are regulated by the state and the rest by the federal government.

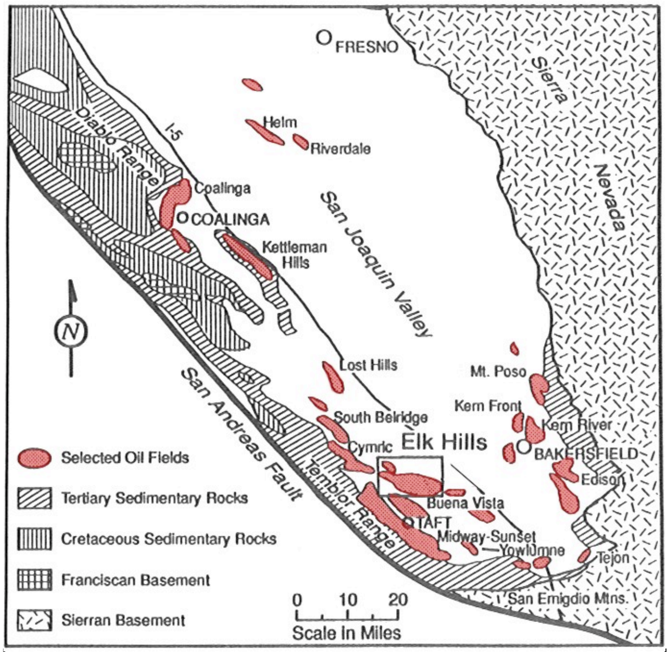


Figure 5. Cartoon of San Joaquin sedimentary basin highlighting selected oil fields (from Reid and Wilson, 1990). Note that many are within 20 miles of the San Andreas Fault. 38,733 wells within this entire region produced 217.3 million barrels of oil or 71% of California's oil in 2000.

Damaging earthquakes have also been a part of California's history killing hundreds of people and causing hundreds of millions of dollars of damage over time. In available accounts of damage caused by major earthquakes, damage to wells and ensuing oil spills is not mentioned (e.g. Dept. of Conservation; von Hake, 1971). An official from California's Division of Oil, Gas and Geothermal Resources which regulates drilling and production of wells could recall no instance of damage done to offshore production facilities by an earthquake. An earthquake near Coalinga (Fig. 5) (M=6.7, 1983) on a blind thrust caused minor damage to storage tanks which were stressed by sloshing fluids. In any event these tanks are surrounded by berms to protect against the more imminent danger of leakage from corrosion. However, nearby houses and commercial buildings of unreinforced adobe and concrete were heavily damaged leaving 1,000 people homeless.

Spills from blow-outs were not unusual in early days of drilling, but engineers learned to control the spontaneous flow of oil out of most pressured zones. The last major blow-out offshore occurred in 1969 off Santa Barbara in federally regulated land. The state placed a temporary moratorium on drilling offshore until stricter regulations were in place to prevent another such occurrence. The blow-out was not caused by an earthquake but rather the simple effect of drilling into a highly pressured zone. Since that time exploration and production have been highly regulated but active at a modest level. Eleven development wells were drilled in Federal lands in 2000. In 1995 ARCO and a subsidiary spent US$ 2.8 million on a 3D survey covering a 10 square mile area off Long Beach to develop a drilling program.

Seismic activity creates some risk but geologically has created structures favorable to trapping hydrocarbons. Slight compression across the plate boundary has folded and faulted the adjacent basins into structures which trap hydrocarbons; the same kind of structures are observed in Hecate Strait.

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Appendix 10: Non-Potential of Natural Gas Hydrate Occurrence in Queen Charlotte Basin[8]

Natural gases such as methane, ethane, propane typically occur as a gas phase on the Earth (Figure 1, Kvenvolden and Lorenson, 2001). However under quite special conditions these gases can combine with water to form a solid form called "Gas Hydrate", or "clathrate". Globally these gas hydrates represent a tremendous reserve of natural gas, especially methane, in the Earth. The global amount of natural gas tied up in hydrates is estimated to be 10,000 Gt or 2 x 10^{16} m^3 (= 6 x 10^5 tcf), e.g., Kvenvolden (1993). For comparison Figure 2 shows the amounts of natural gas contained in conventional reservoirs is about one-half of this amount. The west coast of North America, including the west coast of Vancouver Island is well known to have large accumulations of gas hydrate in the specific shallower (ca. 0 – 250 m) offshore sediments. Because of the potential economic significance of these hydrates, there is considerable interest in their formation and occurrence.

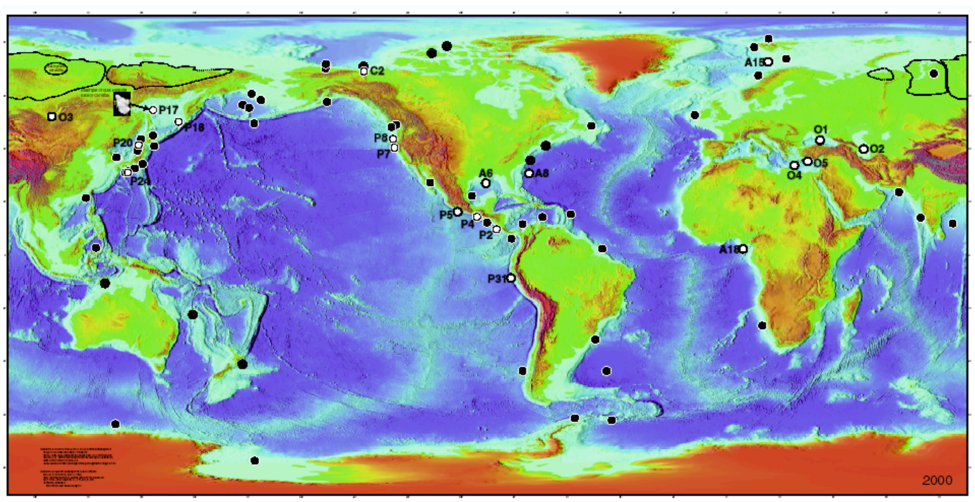

Figure 1. Global distribution of natural gas hydrates (after Kvenvolden and Lorenson, 2001).

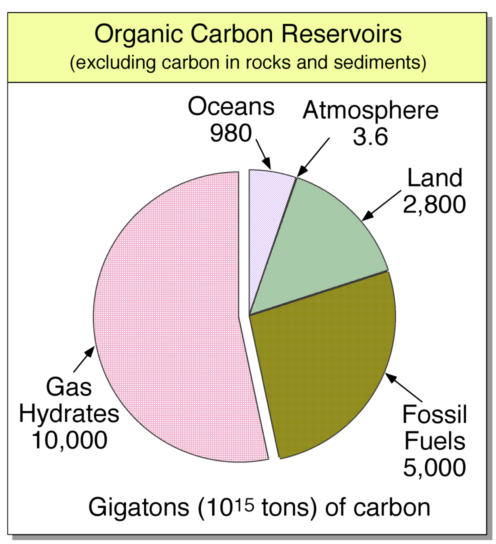

Figure 2. Major organic carbon pools (after Whiticar, 1990)

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8 Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

In addition to their economic potential, gas hydrates are of interest because they:

1. Pose geotechnical concerns, such as large-scale submarine slumping ,

2. Can cause difficulties during drilling operation due the possibility of overpressured gases beneath the gas hydrate stability zone,

3. Are a major factor in greenhouse gas storage and climate change.

There are three primary conditions that must be satisfied in order that methane hydrates are naturally able to form and be preserved. These are:

1. Sediment porewaters (or rarely water column) is saturated with CH_4 (free gas)

2. Sufficient pressure is available (hydrostatic pressure, P)

3. The temperature (T) of the water and sediment is suitably cold.

The first condition, i.e., that the waters are saturated with respect to methane is frequently met in shallow coastal waters, such as found in the Queen Charlotte Basin. There are numerous sources for this methane, but most commonly in this setting the gas is of bacterial or thermogenic origin, e.g., Whiticar (1990).

The combination of temperature and pressure (water depth) necessary for methane hydrate formation and stability are shown in Figure 3. In the lightly shaded region, the pressure is either too low (too shallow) or the temperature too high for hydrate to exist (e.g., Sloan, 1998). The darker region in Figure 3 shows the depth-temperature (P, T) region in which gas hydrate is stable. For illustration, the range in temperature and water depths in the Hecate Strait are given as the white box in the figure. The specific situation in the Hecate Strait is more clearly indicated in Figure 5. This figure incorporates the usual maximum and minimum temperatures measured at different water depths in the summer and winter (Crawford, 2001). The maximum temperature of ca. 16°C is recorded in the summer surface waters (Figure 4, after J. Gower and J. Wallace, Institute of Ocean Sciences, DFO, Sidney). The coldest water is 5 – 6°C in the deeper waters, e.g., 200 m.

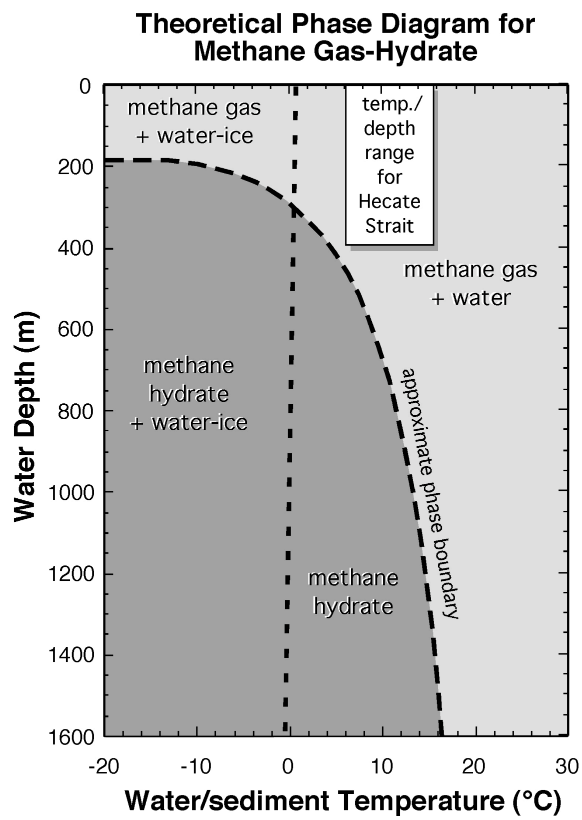

Figure 3. Phase Stability of methane and methane hydrate (after Sloan, 1998)

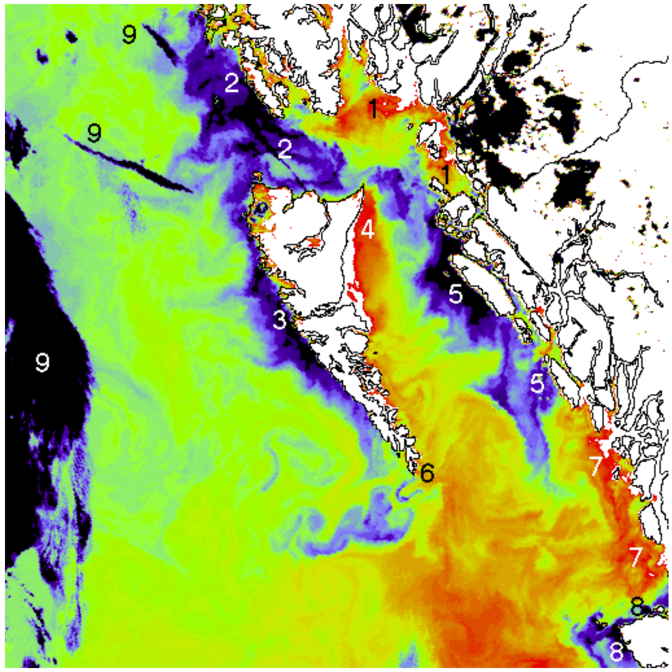

Figure 4. Summer surface water temperature (after Gower and Wallace, 2001) Cool water (10°C appears blue, warmer waters are in red, ca. 16 °C).

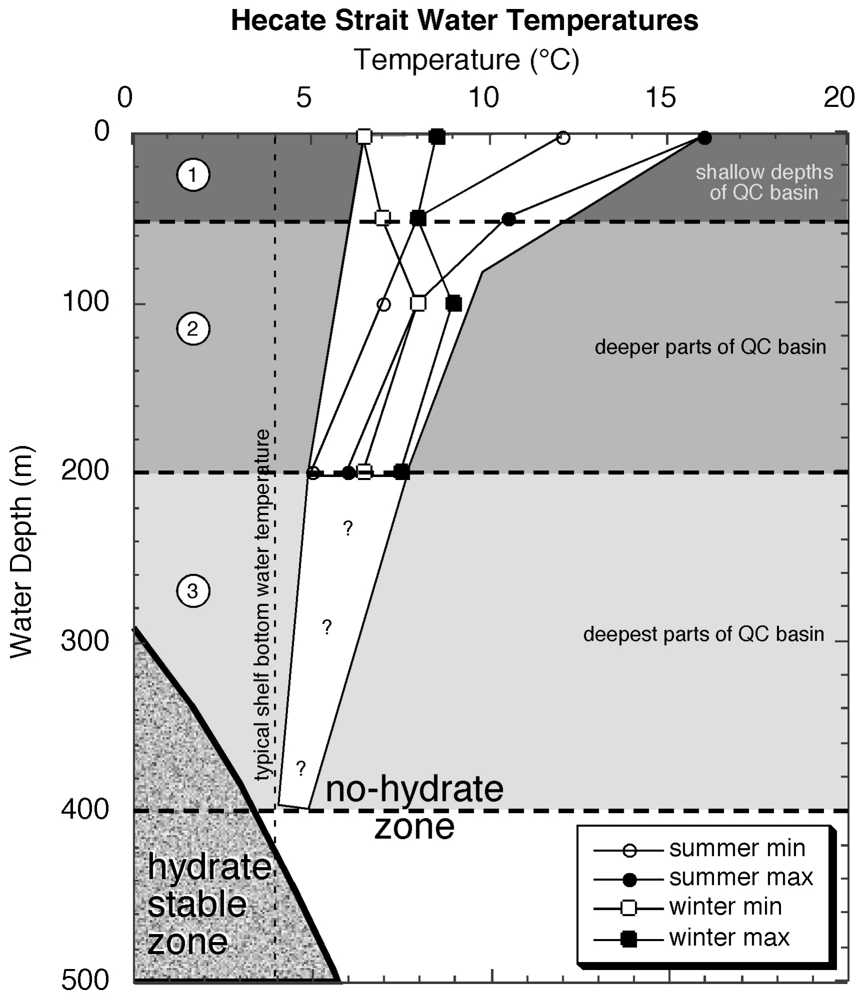

Figure 5. Hydrate non-occurrence in the Hecate Strait

Figure 5 shows this temperature distribution with depth together with the known P,T methane hydrate stability zone. This figure clearly illustrates that even if the waters were saturated with methane the typical waters of the Hecate Strait are not within the hydrate zone. The form of any methane in these waters would be either dissolved or free gas. The situation does not change in the sediments, i.e., any hydrocarbons gases would be in gas form and not hydrate. This is because the temperature will continue to increase with sediment depth due to the geothermal gradient.

It should be noted that offshore, where the water depths (pressures) are greater and the bottom waters are colder (2 – 4 °C), hydrates are stable and can accumulate. However, these hydrates only form if sufficient gas is present. Such is the case in the areas such as the Cascadia Margin, e.g, off Vancouver Island and Oregon coast.

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Appendix 11: Overview of Geologic Hazards to Offshore Petroleum Development – British Columbia Continental Shelf[9]

Introduction

Geologic hazards are those conditions or active processes which pose a potential threat to petroleum exploration or development activities, or to the longer term security of seafloor production installations (e.g., wellheads, pipelines). In many instances these hazards are interrelated (e.g., earthquakes and slope stability) and in others can be related to oceanographic conditions (waves and currents, and sediment mobility). Extreme oceanographic conditions themselves will not be considered in this brief overview whereas sediment mobility as a resultant hazard will be addressed. Clearly other hazards also exist, including oceanographic, meteorological and anthropogenic; these are not considered here.

The following summary will examine the important geologic hazards which exist in various areas on the exposed continental shelf off British Columbia. These include: bedrock outcrops; Holocene faults and associated seismicity; boulder beds; sediment mobility (large bedforms in high wave and current regions); mass wasting (underwater landslides); steep slopes; shallow gas; and, dynamic coastal processes. The scenario envisaged is one of offshore development and production with associated pipelines which traverse the shelf to an unspecified coastal site.

Clearly the regional understanding of seabed geological hazards is only as good as the overall knowledge of the surficial geology in the area. This has been assessed in an accompanying report. As well, many of the specific requisite studies to assess the extent and nature of certain hazards have not been carried out even in areas for which moderate to good knowledge of the surficial geology exists.

Nature of Geologic Hazards

Bedrock Outcrop

Extensive areas of outcropping bedrock at the seafloor could be problematic for drilling and may inhibit burial of pipelines. While burial of pipelines may not necessarily be a requirement everywhere, there would probably be zones where it is highly desirable (e.g., areas which may remain open to fishing; coastal approaches, etc.). Even if burial is not undertaken, outcropping bedrock can present concerns particularly in high current areas; lateral stresses on pipelines from strong seabed currents or "strumming" of the pipeline in areas of spans can result. Spans, if too great, can cause significant stresses in pipelines, shorten the design life of the structure and possibly lead to mechanical failure.

Holocene Faults and Associated Seismicity

Ground accelerations resulting directly from earthquakes can have both direct and indirect effects on all phases of offshore petroleum activity from exploration through to production. Lateral and vertical displacement (and possible rupture or collapse) of rigs and pipelines would be extreme direct effects of fault offset or extreme ground motions. Indirect effects, discussed in greater detail below, include sediment liquefaction and collapse, and a variety of mass wasting processes. All of these could impact wells or seafloor structures, including pipelines.

All of the areas under consideration that lie north of Barkley Sound on southern Vancouver Island are within Canada's highest earthquake hazard category. These areas can expect a greater than 10 percent chance of having ground accelerations exceeding 0.32 g and horizontal velocities exceeding 0.32 ms^{-1} within a 50 year period.

Boulder Beds

Surficial boulder and cobble concentrations exist in many areas of the British Columbia continental shelf and within some of the unconsolidated glacial sedimentary units. They pose concerns for drilling operations

[9] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Brian Bornhold and John Harper, December 2001.

and pipeline burial and, in the absence of burial, can result in a highly irregular surface which can lead to significant pipeline spans.

Sediment Mobility

Seafloor sediments are subject to transport by surface waves and tidal currents over much of the continental shelf of British Columbia. As a result of the exposed conditions and high wave regime in much of the area, large (about 0.5 –1.0 m) sedimentary bedforms (oscillation ripples and megaripples) in coarse sands can be produced by surface waves in water depths in excess of 100 m. Similarly, topographically constrained tidal currents in some localities can result in migrating sandy bedforms (sand waves) which are more than 5 m in amplitude. Larger accumulations of mobile sands and gravels, sand ridges, can be up to 10 m high, one hundred metres wide and several hundred metres long.

A highly mobile seabed can have several impacts including burial, scour and lateral dislocation of surface-laid structures (e.g., pipelines), spans which result from removal of sediment beneath pipelines, and abrasion of rigs , wellheads and pipelines by the moving sediment.

Mass Wasting

A variety of slope failure processes in zones of high relief can pose significant hazards to rigs, wellheads and pipelines. These include liquefaction failure and collapse, direct lateral impact from moving sediment masses on rigs, anchors and pipelines, and scour by flow slides and turbidity currents. Causes of mass wasting can include earthquakes, storms and rapid sediment deposition on steep slopes.

Steep Slopes

Steep slopes of diverse origin can be of concern for pipeline routes and production facilities. Construction on steep slopes may, in some instances, require added measures to ensure that pipelines are stabilized. Slopes pose a particular hazard when coupled with other conditions or geological processes (e.g., shallow gas, earthquakes or slope instability). Scarps and slopes may be wave-cut in shallow water (or as relict deeper water features), the result of current erosion, past glacial erosion, tectonic processes (faulting) or mass wasting.

Shallow Gas

Accumulations of biogenic gas (primarily methane) are common in areas of present day mud accumulation on the shelf and especially in coastal fjords. Gas seeps into the water column from a deeper petrogenic source are much less common but do occur on the British Columbia continental shelf especially in Hecate Strait. Gassy sediments have lower strength than gas-free sediments. As a result, structures emplaced on gas-rich sediments are at risk from liquefaction collapse and possible downslope failure. Sediment strength can be completely lost, for example, during earthquakes when trapped interstitial gas is suddenly released to the water column.

In some areas gas escape structures (pockmarks) on the seafloor have been mapped. Gas escape during some drilling operations can pose a hazard.

Dynamic Coastal Processes

Coastal processes, such as high rates of erosion and longshore drift, are of particular concern for landfalls of pipelines. These facilities must be designed so as to be protected from exposure, dislocation and possible rupture throughout the entire design life of the facility. In some areas, rates of coastal erosion are in excess of several metres per year and would necessitate adequate burial and setbacks of coastal terminations to account for changes which would be anticipated over the course of several decades.

Regional Summary

Vancouver Island Shelf

Bedrock Outcrop. Bedrock outcrop dominates in the very nearshore area of most of the west coast of Vancouver Island. Elsewhere, extensive exposed bedrock outcrop occurs on the inner shelf north of Nootka Sound and especially in a broad area around the Scott Islands. These areas include zones of exposed low-relief sedimentary rocks (mostly mudstones) south of Brooks Peninsula and around the Scott Islands; a band of discontinuous, high-relief, rugged volcanic rocks extends from Brooks Peninsula towards Cape Scott. Elsewhere on the shelf Holocene sediments are very thin and often absent; locally exposed low-relief Tertiary bedrock and Quaternary sedimentary units occur at the seabed in these areas.

Holocene Faults and Associated Seismicity. The Vancouver Island continental margin is a subduction zone, where the Explorer and Juan de Fuca plates are descending beneath the western edge of the North America Plate. Thus, the area is seismically very active with the potential for catastrophic giant or megathrust earthquakes (>M8.0). Numerous faults of different types exist throughout the area: several shallow faults are known to displace Pliocene and Quaternary sediments on the shelf and are associated with topographically significant structures (anticlines) on the mid-shelf off Nootka Sound; the Nootka Fault is a coast-normal transform fault which extends into Vancouver Island (separating the Explorer from the Juan de Fuca Plate) with significant associated seismicity; crustal earthquakes with historical magnitudes as high as M7.0 (1918) and M7.3 (1946) are frequent on Vancouver Island.

Boulder Beds. Since the Vancouver Island shelf was minimally galciated north of the latitude of Tofino, boulder beds are concentrated on the mid-shelf only on banks around the troughs off Barkley Sound. Boulders up to several metres in diameter have been identified in these morainal deposits. Elsewhere, boulder and cobble concentrations are restricted to inner shelf and coastal areas

Sediment Mobility. Wave-generated ripples and megaripples (about 0.5 m amplitude) are known from the shelf north of Brooks Peninsula in water depths of more than 100 m water depth and on the mide-shelf off Barkley Sound. It is expected that similar features will exist on other parts of the Vancouver Island shelf as well. Current-generated sedimentary structures, including relatively thin rippled sand ribbons occur near the Scott Islands where tidal currents pass between the islands. Some sediment transport by tidal currents has also been documented in the vicinity of high-relief bedrock on the inner shelf north of Brooks Peninsula and along the perimeter of the glacially carved troughs off Barkely Sound where fine sediments are accumulating.

Mass Wasting. Mass wasting is known from only two settings on the Vancouver Island shelf: the shelf edge and within the troughs on the inner and mid-shelf off Barkley Sound. Canyons indent the edge of the continental shelf at water depths of 200-250 m; the heads of these canyons are sites of steep scarps and significant mass wasting. The glacially carved troughs off barkley Sound are characterized by steep slopes and localized failures.

Steep Slopes. High relief is present on the outermost shelf, especially in the vicinity of canyon heads, along the outer margins of the Barkley Sound troughs and on the rugged bedrock areas north of Brooks Peninsula.

Shallow Gas. Shallow gas is not common on the Vancouver Island shelf except in the fine sediments accumulating in the Barkley Sound troughs. Elsewhere the Holocene sedimentary cover is very thin (< 0.5 m in general). Gas is common in the muddy sediments accumulating in the many fjords along the coast and gas hydrates are known to occur on the continental slope of Vancouver Island.

Dynamic Coastal Processes. Sedimented coasts are most prevalent south of Hesquiat Peninsula to Barkley Sound and in the vicinity of Cape Scott. Low-gradient extensive beaches with fine to medium sands prevail in the Long Beach area near Tofino. Elsewhere the coastline is predominated by bedrock with small embayed beaches of generally coarser sediments.

Queen Charlotte Sound

Bedrock Outcrop. Exposed bedrock mainly occurs in the vicinity of the Scott Islands, and in a broad zone of rugged relief in easternmost Queen Charlotte Sound adjacent to the British Columbia mainland. Minor local occurrences have been documented from the southern banks in the central part of the sound.

Holocene faults and Associated Seismicity. The region lies opposite the ridge-trench-transform triple junction located along the continental margin. Thrust faulting dominates to the south and along Vancouver Island while dextral strike slip motion occurs to the north along the Queen Charlotte Transform Fault. While Queen Charlotte Sound lies adjacent to one of the most seismically active areas in Canada, few earthquakes of M5 or greater have actually been recorded in the sound. Faulting in Tertiary strata in Queen Charlotte Sound is well documented but no faults are known to offset Quaternary strata or break through to the seafloor. That being said, faulting related to Quaternary post-glacial loading and isostatic rebound has been documented along some of the prominent glacial troughs which travese the shelf. These troughs do not appear to owe their origin to underlying Tertiary faults.

Boulder Beds. The only known areas of boulder fields are in the northeasternmost part of Queen Charlotte Sound along the eastern edge of Moresby Trough. Gravelly and cobbly sediments occur frequently on the three banks in the central part of the sound.

Sediment Mobility. The highly exposed banks of Queen Charlotte Sound exhibit abundant evidence of sediment mobility in the form of megaripples, linguoid ripples, sand ribbons and sand waves. These features are most prevalent on and around the major banks in the central part of the sound to water depths of about 200 m. Oscillation ripples have been documented on the outer shelf of the southern banks to water depths of 90 m. Erosion of sediments by topographically enhanced tidal currents is known from several of the troughs which cross the sound.

Mass Wasting. Mass wasting is known only from the steep margins of Moresby Trough along northern Queen Charlotte Sound and in the complex region of canyon heads which incise the central shelf edge.

Steep Slopes. The area was traversed by glacial tongues emanating from the British Columbia mainland fjords through Hecate Strait. These glaciers incised prominent troughs through the shelf area resulting in locally very steep slopes. Of greatest importance in this regard is Moresby Trough along the northern edge of the sound where slopes in excess of 15^{o} are common. Other steep slopes occur on the outer continental shelf where canyons indent the continental margin.

Shallow Gas. Shallow biogenic gas accumulations are only known from the deeper parts of Moresby Trough (about 300-400 m water depth). Pock marks or gas escape structures occur in about 150-250 m water depths in the eastern part of the sound; gas in the underlying sediments was not detected acoustically in these areas.

Dynamic Coastal Processes. There are no significant areas of sedimented shorelines where extensive erosion, sediment transport or deposition are occurring. Most of the coastlines surrounding the sound are rugged bedrock with only localized embayed beaches.

Hecate Strait

Bedrock Outcrop.Outcrop at the seafloor is restricted primarily to the eastern margins of the strait, in a broad zone of complex and rugged topography along the mainland coast, and along the eastern side of Moresby Island. Outcropping bedrock is not known from the central parts of the strait except in the walls of southernmost Moresby Trough.

Holocene Faults and Associated Seismicity. The region lies adjacent to the Queen Charlotte Transform Fault along which the largest recorded earthquake (M8.1) occurred

in 1949. While the region was sparsely populated at the time, this earthquake caused considerable damage in the Queen Charlotte Islands and in Prince Rupert. While there are many known Tertiary faults in Hecate Strait, little recorded seismicity appears to be associated with them and there are no documented instances of seafloor displacement. Any Quaternary faulting in the area appears to be related to isostatic rebound and post-glacial loading

Boulder Beds. Boulder fields are known to occur on some of the shallow banks (e.g., Laskeek Bank) and along the slopes of Moresby Trough. Dogfish Bank off Graham Island is poorly studied but is anticipated to have many areas of boulder concentrations.

Sediment Mobility. Sand waves are common along the margins of Dogfish and Laskeek Banks, particularly on the steep bounding slopes leading to Moresby Trough. As well, linguoid bedforms and sand waves are found in the narrow channels between southwestern Laskeek Bank and Moresby Island in southern Hecate Strait; amplitudes of these features can exceed 3 m.

Megaripples, sand waves and sand ridges are particularly important in the vicinity of Rose Spit and Rose Bar at the northeast corner of Dogfish Bank. These features are the result of storm-driven sand motion on the shelf under the influence of topographic steering of tidal and wind-driven currents. In this area amplitudes of the sand waves and sand ridges can exceed 6 m.

Mass Wasting. Slope failures have been identified from several localities in Hecate Strait, particularly along the steep slopes of Moresby Trough and in the deeply incised channels between Laskeek Bank and Moresby Island.

Steep Slopes. Wave cut terraces, produced during periods of lower sea level stand in the early Holocene mark the western edge of Moresby Trough through out Hecate Strait. As many as three separate “steps” in the seafloor topography occur and can be traced over many tens of kilometres; each “step” is from 10 to 30 m and can exhibit slopes greater than 15^{o}. Steep slopes also exist along the margins of some of the deeply incised troughs between Moresby Island and Laskeek Bank in southern Hecate Strait.

Shallow Gas. Shallow gas concentrations are common throughout the deeper parts (> 100 m) of Moresby Trough where thick sequences of muddy Holocene sediments have accumulated. As well, local occurrences of gas exist along the easternmost edge of Dogfish Bank; it is conceivable that these may have a deeper petrogenic origin.

Dynamic Coastal Processes. The eastern coastline of Graham Island is largely dominated by a thick sequence of unconsolidated glacial outwash deposits capped locally by Holocene dunes. These sediments are retreating rapidly, with the eroded sediments being swept northwards towards Rose Spit. While average erosion rates apear to be about 1 m per year, retreat is highly episodic; in 192-1993, for example, 11 m of land was lost at Cape Fife and 1.5 m was lost in a 24-hour period at the same site in 1994. Numerous, ephemeral shore-attached bars are associated with the high rates of longshore drift along eastern Graham Island.

Dixon Entrance

Bedrock Outcrop. Rugged outcrops of bedrock occur at both the eastern and western extremities of Dixon Entrance on Celestial Reef and Learmonth Bank. Along the nothernmost edge of the strait, adjacent to Alaska, bedrock reefs extend offshore. Nearshore areas are characterized by outcropping bedrock in the easternmost parts of the strait and along Graham Island, particularly west of Masset Inlet. Low relief sedimentary bedrock of Tertiary age outcrops locally on the eroded seabed in McIntyre Bay.

Holocene Faults and Associated Seismicity. Many faults have been identified in the sedimentary bedrock which underlies Dixon Entrance and at two localities, immediately east of Learmonth Bank and adjacent to a zone of exposed bedrock in central Dixon Entrance, normal faults which cut the present seafloor have been inferred. There is no documented association between these faults and historical seismicity in the area. Dixon Entrance lies immediately adjacent to and east of the Queen Charlotte Transform fault which is seismically very active; Canada’s largest recorded earthquake (M8.1) occurred along northwestern Graham Island just south of the entrance to the strait.

Boulder Beds. Concentrations of boulders are common in Dixon Entrance from nearshore areas, especially off Graham Island west of Masset, on prominent banks and over large areas in the central strait to water depths of 250-350 m.

Sediment Mobility. Sedimentary bedforms indicative of active seafloor processes occur in several localities within Dixon Entrance. Of note are the large features located on the shelf north of Graham Island west of Masset. Megaripples, oscillation bedforms and sand waves occur in this area to water depths of up to 100 m. Similar features up to 2 m high have also been documented about 20 km north of Rose Spit in 150-200 m water depth on the flanks of a small topographic high. Relict deep water (>400 m) features also occur in Dixon Entrance and are believed to have been created during times of lowered sea level.

Mass Wasting. No specific examples of mass wasting have been identified in Dixon Entrance. This most probably is simply a reflection of the nature of surficial geology investigations in the deeper parts of the strait which have been restricted to coring and widely spaced seismic profiles. It is expected that failures will be concentrated near steep scarps at the edge of the shallow shelf off Graham Island and around the bank areas in the eastern and western strait (e.g., Learmonth Bank).

Steep Slopes. A wave-cut terrace and scarp lies off Graham Island just north of Masset in approximately 55 m water depth. Locally this scarp is more than 20 m high. Elsewhere steep slopes are mostly associated with bedrock-cored banks and shoal areas along the northern side of the strait, and at its eastern and western extremities.

Shallow Gas. The most significant area of biogenic gas accumulation in Dixon Entrance lies south and southeast of Celestial Reef (west of Dundas Island) in a thick sequence of Holocene muds. These sediments lie in 100-200 m water depth.

Dynamic Coastal Processes. The coastline of McIntyre Bay off northeast Graham Island is the result of beach ridge accretion over the past several thousand years. Sediments are swept southeastwards from the bay into the coastal zone. There is still debate as to whether sand from south of Rose Spit brought northward by longshore drift is a source of additional sand for these beach ridges. The significant longshore drift in McIntyre Bay is towards the northeast (Rose Spit). Elsewhere in Dixon Entrance the coastline is mostly bedrock-dominated with short embayed beaches of coarse sediments.

Regional Sensitivity to Oil Spills

Although the potential for a catastrophic oil spill from an uncontrolled blow-out is remote, the possibility does exist and is of significant concern in the planning process. A spill in the region would almost certainly impact shorelines, could impact sensitive biological resources and will alter human-use activities, such as tourism, commercial and recreational fishing. The province (Ministry of Sustainable Resource Management) is presently near completion on a province-wide coastal inventory that incorporates a state of the art. oil spill sensitivity analysis (see Howes *et al* 1993; 1999); however, the North Coast region is one that remains incomplete at present (the sensitivity model may be complete in 2-3 years, depending on level of support from the provincial and federal governments). This sensitivity model incorporates sensitivities of resources to both spills and to spill cleanup efforts.

In modeling studies of possible blow-out scenarios, Chevron (1984) showed a general *zone of influence* from a catastrophic blow-out (Fig. 1). This *zone of influence* shows that oil could reach almost all shorelines around Queen Charlotte Sound, Hecate Strait and Dixon Entrance, including southeastern Alaska, Queen Charlotte Strait and Quatsino Sound. There are more than 18,000 km of shoreline within this *zone of influence*, although it is important to note that in event of an actual spill, the length of shoreline that could be oiled would be significantly less – the length of shoreline oiled in the *Exxon Valdez* spill was around 2,000 km, most of which was very light oiling (Table 1). The concept of a *zone of influence* is useful for delineating the total area that should be considered as part of the planning and evaluation process.

Table 1 1989 Shoreline Oiled (km) in the Exxon Valdez Spill (from Exxon 1991)

Category	Prince William Sound	Kenai-Kodiak	Total
heavy oiling	144	24	168
moderate oiling	96	24	120
very light to light oiling	531	1,255	1,786
		Totals:	2,074

Physical Sensitivity

Because the formalized oil spill sensitivity model has not been completed for the Mid- and North Coast Region, only a first approximation of sensitivity is possible. Two of the primary assumptions of the provincial spill model are (Howes *et al* 1993; p. 14):

- "*the oil residence determines the probable exposure of resources to oil*",
- "*oil residence on the shoreline is based on the physical properties of the shore*".

A generalized knowledge of the physical properties of the shore can be used as a first step in constructing a generalized sensitivity assessment (inset).

The generalized wave exposure categories for the North Coast region are illustrated in Figure 2 (after Howes *et al* 1997). The low wave exposure portion of this coastline comprises about 14,000 km, a substantial portion of the total coastline (~ 75%; including portions of southeast Alaska). This low energy shoreline is coast where one would expect substantial oil residence periods (months to years) if oil were stranded along the shoreline.

Detailed shoreline mapping of one portion of the North Coast has been completed with the Gwaii Haanas National Park Reserve (approximately 1,600km of shoreline; Harper *et al* 1994). The detailed mapping shows that about 55% of the shoreline is bedrock and 45% either sediment or a mixture of rock and sediment (gravel or sand & gravel); these types of sediment shoreline are moderately to highly permeable and would have generally moderate to high oil retention in the event of a spill. The substrate results are probably representative of other areas of the North Coast and suggest that about 50% of the coast has sediment or mixed rock and sediment shoreline of moderate to high permeability sediments.

Although this assessment is very general, it is clear that: (a) there are substantial portions of low wave exposure coastline on the North Coast; and, (b) a substantial portion of this low wave exposure shoreline has moderately to highly permeable sediments. The assessment suggests that a substantial portion of shoreline, about 6,000 km or 35% of the total, will have the highest oil residence class, with month to years of possible oil residence. There would be another 6,000 km of low energy, bedrock shoreline that will have moderate oil residence periods.

Physical Shoreline Properties

Influencing Potential Oil Residence

Wave Exposure – wave exposure is probably the most important factor supplying energy to the shoreline and is critical to the mechanical dispersal of stranded oil. High wave energy levels generally result in rapid mechanical removal of the oil from the shoreline; that is, a rapid natural recovery process. Shorelines with low wave energy levels typically show lengthy oil persistence due to the slow mechanical dispersal of stranded oil. This assumption is incorporated into the BC provincial sensitivity analysis (Harper *et al* 1991) and is incorporated into more generalized sensitivity analyses used worldwide (see Halls *et al* 1997). The assumption for this first approximation is that high wave exposure shorelines will have short oil residence periods (days to weeks) and that low wave energy shorelines will have lengthy oil residence periods (months to years).

Sediment Permeability – shoreline sediment permeability influences the depth of penetration and the volume of oil that is retained along different shoreline segments. Impermeable substrates such as bedrock or mudflats have low penetration, low overall retention and as a result, relatively short oil residence periods. Highly permeable substrates such as boulder and cobble beaches permit considerable penetration of stranded oil (>1 m) and large volume retention, estimated to be as high as one barrel of oil per linear metre of beach on some sections of the Prince William Sound shoreline that were impacted by the *Exxon Valdez* spill. As such, low permeability shore types are assumed to have shorter oil residence periods than high permeability shore types.

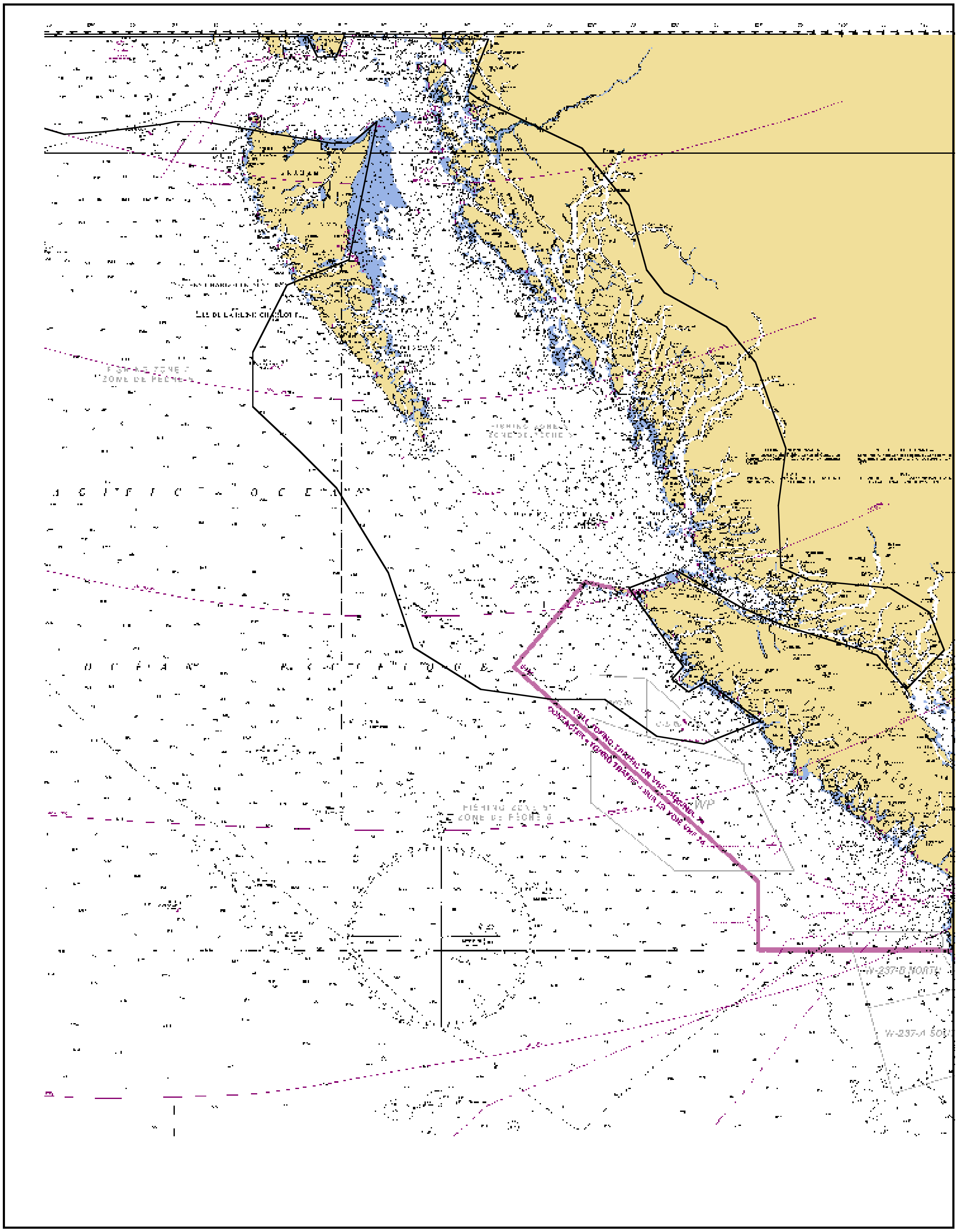

Figure 1Zone of potential* surface *influence of spilled oil from the lease area during* extreme winter *weather.

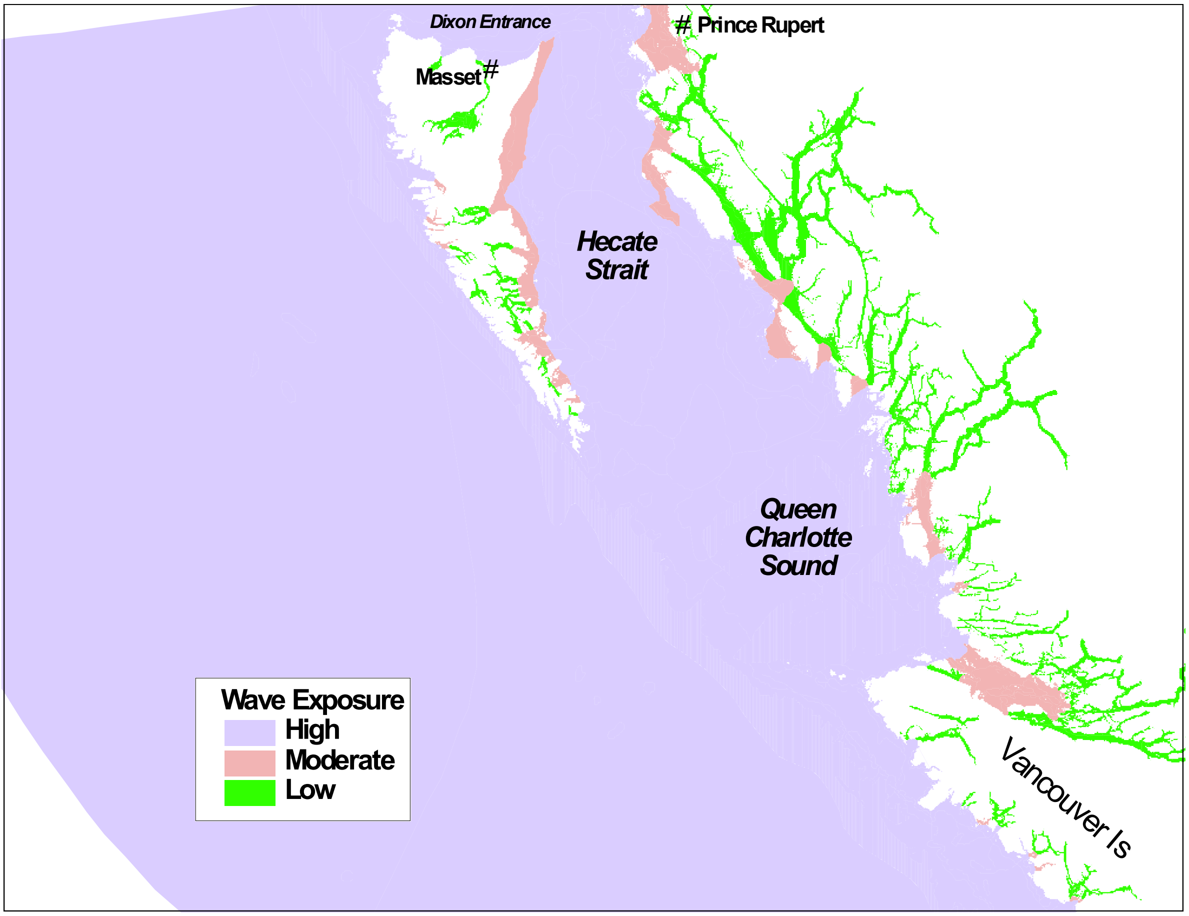

Figure 2. Generalized wave exposure categories of the North Coast (after Howes et al 1997). Low wave exposure areas have high potential for length oil residence (wavexp1.jpg).

Other Resources

This sensitivity assessment does not attempt a rigorous analysis of sensitivities of biological resources to spills but rather identifies some *types* of species at risk. Spill impacts occur at all trophic levels and direct mortality may not be the best index of overall effects. This assessment merely points out some of the species at risk and general information about these species that could be used to more quantitatively assess sensitivities.

Oil spilled at sea will weather in a variety of ways including photo oxidation, evaporation, dissolution and dispersion into the water column. The bulk of most spills remains on the water surface during the initial part of the spill. Organisms that spend most of their time living or feeding on the water surface are particularly vulnerable to spills. These include sea birds, shore birds and marine mammals. Most birds are highly sensitive to spill effects either through loss of insulation caused by direct oiling of feathers or by ingestion of oil from the preening of feathers. Many marine mammals are not as sensitive to oiling (e.g., seals, whales) but some, such as sea otters or fur seals are highly sensitive.

Of particular concern are high concentrations of species such as those that may occur around bird colonies, intensive feeding areas or seal pupping areas. For example, the Goose Group of islands in eastern Queen Charlotte Sound contains a unique population of sea otters; the entire population is contained in less than a 20 km^2 area. Significant portions of the population of ancient murrelets and Cassin's auklets (40 percent of the world's breeding population) nest on a few islands of the Queen Charlottes, making this particular species sensitive to "population"-scale impacts from a spill at the right time in the right area. The location of bird colonies and their approximate size is well known so the sensitivity of these resources should be "quantifiable". Offshore feeding areas are less well known, however, and there could be large aggregations of seabird along "fronts". The location of sea otter populations is generally well known and the sensitivities to spill impacts quantifiable.

Shore spawning areas for fish are a concern during spills. Anadromous fish pass through the nearshore zone enroute to spawning streams and some species, such as herring and pink salmon, spawn in the nearshore. Locations of anadromous fish streams are well documented as are commercial spawning areas of herring so that spill sensitivities for these commercial species are quantifiable.

Intertidal shellfish are potentially at risk from spills, although usually from sub-lethal effects rather than direct mortality. The distribution of commercial beds is well known but the distribution of non-commercial species is not well documented.

Fish are generally at lower risk from spill impacts than seabirds because they are beneath the water surface and oil concentrations are likely to be substantially lower. It is assumed that groundfish species that are concentrated near the shore would be most vulnerable to impacts. The Ministry of Environment (1983) shows substantial groundfish spawning areas in the vicinity of Dogfish Bank near eastern Graham Island but the nearshore of the entire *zone of influence* is probably utilized for non-commercial groundfish spawning. Generalized impacts such as these, as well as impacts to intertidal flora and fauna, can be estimated with the Provincial coastal sensitivity database, which is partially complete at the present time.

Mitigation Potential

There is the potential to mitigate impacts of spills by preventing oil from reaching the shorelines either through the use of dispersants or through protection booming. The use of dispersants, typically applied from aircraft, can be effective but is always controversial (see Ministry of Environment 1983, Appendix III) - dispersants are perceived by many as having significant impacts on fish and pre-approved dispersant use plans are required for rapid deployment in event of a spill (must be applied within 24 hr).

Containment booming of oil spills is not effective in high wave or high current areas, a substantial portion of the region in question. Even in low current and low exposure areas, the remoteness of most of the coastline from response centres would result in longer than 48 hr response time. It is unlikely that any more than a very small portion of the coast could be protected by booming in the short term (48 to 72 hr).

Dispersant application within 24 hr of the spill represents the only reasonable mitigation strategy. However, having a pre-approved dispersant application plan cannot be assumed as dispersant use is highly controversial. At present there is no pre-approved use of dispersants anywhere in Canada.

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Appendix 12: Introduction To The British Columbia Coastal Resource Programs[10]

Program Overview

The Province of British Columbia (BC) has been involved in the management of coastal resources since the 1800's. Today, the provincial government is responsible for the management of over 29,500 km of shoreline and seabed in the inshore and nearshore waters of BC, and works with other levels of government on the management of resources under federal and local jurisdiction.

BC has developed a number of coastal resource programs in support of initiatives to address economic development and diversification, coastal threats, land and resource conflicts, First Nations issues, and to support informed decision making in the coastal zone.

Many of BC's provincial coastal inventory and analysis programs are managed by Decision Support Services (DSS) of the Ministry of Sustainable Resource Management. Given the multi-jurisdictional nature of coastal environments, DSS has been tasked with the co-ordination of coastal resource, inventory, analysis, and certain policy development programs.

This summary provides a brief overview of coastal resource programs in BC, and where to get further information on each of these programs. Detailed summaries of these programs are under development on the DSS website at srmwww.gov.bc.ca/dss.

Program Components

Coastal Inventory and Information Management

Information is fundamental in developing any comprehensive coastal planning or resource application. BC has been collecting coastal resource data in a systematic and synoptic manner since 1979. Resource information is collected using peer-reviewed provincial Resource Inventory Committee Standards which include standards for data management and analysis. Types of environmental resource information collected includes oceanographic, physiographic, and biological data. Examples of human-use information collected includes data on fisheries, traditional knowledge, coastal tenures and land uses, and recreation and tourism use and capability.

Coastal resource information is stored in the Coastal Resource Information Management System (CRIMS). This system is used to provide data and analyses for coastal resource management, conservation, protection and planning applications. Key components of this system include, data management, access, analysis, and the design of resource models to develop products for conservation, planning and resource management. The CRIMS currently consists of several integrated technologies including GIS and image processing software, digital video, and attribute data management system and a trajectory model (for oil spills). These different technologies have been integrated into a single system that is accessed through a custom designed user interface.

Oil Spill Planning and Response

The CRIMS system described above is also a key component in BC's oil spill response and countermeasures program. DSS works closely with the petroleum industry to develop oil spill response and countermeasure strategies for the BC coast. These strategies include the development of the BC Biophysical Shore-zone Mapping System, which involves the systematic mapping of the coast to document the biophysical character of the shore zone. The underlying concept of the system is that the shore zone can be divided into discrete shore units on the basis of its physical character. The basis of the system is a shore unit, which identifies an area where the morphology (shape), sediment texture and physical process do not vary across or along the shore. Each shore unit can be further subdivided into components that are continuous across- or along- shore and are described in terms of their physical characteristics (morphology, sediment texture, dominant processes etc.). This physical system provides the framework for recording the biological character (e.g. species distribution and abundance) of each shore unit. This approach assumes the

[10] By Mark Zachiarais, British Columbia Ministry of Sustainable Resource Management.

physical parameters of substrate, elevation and wave energy, as determined in the physical mapping are the main determinants of species distribution.

Oil spill response and countermeasures atlases have been developed for the west coast of Vancouver Island, the southern Strait of Georgia, and Burrard Inlet (underway) which provide information on coastal biophysical and human use resources and the sensitivity and vulnerability to both oiling and clean-up of these resources.

Marine Protected Areas Strategy

BC currently has 104 provincial and 19 federal Marine Protected Areas (MPAs) which comprise about 4.2% of BC's waters less than 1000 m deep. DSS has developed a number of planning products to advance efforts to establish new MPAs and provide information for enhanced management planning of existing MPAs. These planning products include;

The British Columbia Marine Ecological Classification (BCMEC), which is a hierarchical marine classification consisting of four nested divisions based on physical properties, and a fifth division based on current, depth, relief, substrate, salinity, slope, stratification, temperature and wave exposure. The fifth division – termed ecounits - was created at a considerably larger scale (1:250,000), and is the first example of a large-scale marine classification applied over a large area (453,000 km2). The ecounits were developed to evaluate the boundaries and homogeneity of the four larger divisions, as well as for the application to coastal management and marine protected areas planning.

BC has also developed a preliminary list of Valued Marine Environmental Features (VMEFs), which are key features of marine environments valued for their conservation (i.e. natural environment), recreational and cultural-heritage characteristics. Identification of VMEFs was based on a detailed and multi-disciplinary literature review along with discussions with experts in marine sciences, recreation and cultural-heritage resources. Examples of the various types of VMEFs include:

- Kelp beds - conservation VMEF
- Abandoned canneries - recreation VMEF
- Archaeological sites - cultural / heritage VMEF

BC has also been working on developing a MPA GAP analysis to identify representative and distinctive potential candidate areas for conservation. This work is based on the BCMEC, the VMEF work, and the identification of biophysical and human use values within existing MPAs. This work is also being used to identify existing provincial protected areas which may benefit from fisheries closures using federal legislation.

Coastal Planning, Management, and Monitoring

Since the early 1990's, the province has been using a land use planning framework to resolve land and resource use issues on terrestrial lands, and to assist in implementing the Protected Areas Strategy and Forest Practices Code. A primary emphasis has been on strategic level plans for regions and sub-regions, which then provide direction to more detailed, localized management or development planning.

The province has also initiated a number of integrated, consensus-based coastal management plans at both the strategic and local scales. At present, approximately half of the provincial coastal zone has been zoned by coastal planning, and plans are underway to complete coastal planning throughout the province.

To aid in the ongoing management of coastal environments, the province has initiated the development of a methodology to identify Marine Sensitive Areas (MSAs). MSAs are identified by using systematic intertidal and subtidal inventories to delineate sensitive and vulnerable habitats. The province has currently completed an intertidal MSA methodology and is currently developing a subtidal and offshre MSA methodology.

The province is also developing a trends monitoring program to evaluate environmental trends in the coastal zone as well as the effectiveness of coastal planning and MPA establishment efforts. These efforts are supported by Fisheries and Oceans Canada, Parks Canada and the Department of Natural Resources, Washington State.

Appendix 13: List of Some Comments and Questions Linked to Categories in the 2001 Whitford Report[11]

Comments and questions in this document are prepared in a shortened form (bullets) to highlight some issues related to BC offshore oil and gas development that may need additional attention or research. This document was not intended to be comprehensive.

Presentation/format: Information/action sheets

There is a need to more clearly identify the most important issues/topics to determine "whether BC offshore oil and gas resources can be extracted in a way that is scientifically sound and environmentally responsible".

- Need a list of the key issues/topics and subtopics
- Many of these issues are discussed in the Whitford Report
- Are there additional issues/topics?
- What are the issue/topic inter-linkages?

The clarification could include short information/action sheets (example in Appendix A) that list key information such as:

1) current background information (in bullets) relevant to the issue/topic
2) current issues and concerns
3) images, graphs, charts, maps, etc. that discuss/display the most important aspects of the issue/topic
4) expertise that can address the issue/topic, and research that has been completed, is in progress, is planned, is being thought about, and is needed in future
5) training and employment opportunities
6) priorities, timing, costs, benefits & problems:
   - How important is the issue/topic (high, medium, low)?
   - When does the issue need to be resolved or the topic need to be addressed (before moratorium is lifted, before exploration begins, during exploration or production, before or after decommission, etc.)?
   - What are the $ costs?
   - What are the benefits of each issue/topic?
   - What are the consequences of not doing anything related to the issue/topic?
7) questions
8) and actions that need to be taken.

[11] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Marjorie Johns, November 2001.

By building these information/action sheet-sets, an information resource can be developed. In future, it can be used (part or whole) for reference, presentations, or to build other documents such as an atlas on BC offshore oil and gas resource topics/issues (that could include information from the earliest planning, information, and research stages through exploration and development to decommission). An initial list of possible maps and images are included in Appendix C.

General comments and questions:

BC Offshore basins: - should include the Queen Charlotte, Tofino, and Georgia Basins. The focus has mainly been on the Queen Charlotte Basin (potentially being the largest producer) but the Tofino and Georgia basins also have resource potential (see 2001, Hannigan et al., "*Petroleum resource potential of the sedimentary basins on the Pacific Margin of Canada*", GSC Bulletin 564).

- Is gas or oil more important to produce or do they have equal value within the BC Offshore basins?
- Locally and globally, what are the biggest markets for gas and oil?
- If the offshore basins develop and produce, how will this change other BC and Canadian production?
- Is there any new or old data that indicates where BC offshore exploration may begin?
- Recommended local contact: Dr. Michael Whiticar, University of Victoria. He has compiled an excellent presentation on BC offshore oil and gas.

Expertise, research and training:

- Who are the experts that are needed to undertake research, provide information, data and results, monitor industry activities, and develop policies, regulations, and legislation, etc. (academia, government, industry, consultants, public, others)?
- Who is currently available to provide up-front data and information?
- Who needs to be hired or appointed (governments, academia, industry, etc.)?
- What research has been completed, is in progress, and is planned?
- What research programs are currently addressing some of the issues/topics (e.g. Coasts Under Stress Project: contacts Drs. Rosmary, Ommer, Chris Barnes, Harold Coward, Univ. Victoria)? Additional research and funding could be important for this project and others.
- What research needs to be started and when can it be completed?
- What training is needed?

Obtaining current and relevant information

- What is the best way to obtain current and relevant information from experts (interviews, requests for proposals, public forums, etc.)?

- A literature review is good for finding completed research/reports but is missing active research/studies and proposals and ideas for future projects.
- Collaboration with topic experts is essential for learning about future directions, needed research, and new project ideas.

Need for baseline information on:

- Basin geology, faults, and sedimentology
- Oceanography and climate
- Marine life, habitats, and distributions (we need baseline information to know what life is currently there - to be able to assess later the effects on the environment if there was a contaminant release or spill, or other damage).
- Technology, engineering, and expected use of an area by the industry
- First Nations peoples
- What will happen to BC coastal communities with O&G development
- Regulations, policies, legislation

Industry

- What industries are interested in the BC offshore O&G development?
- What are the needs of industry?
- What are industry's biggest risks, concerns, or limitations?
- Do new technologies need to be developed?

USA's interests

- What are the USA's interests?
- How would BC O&G industry effect trade with the USA?
- Would the USA provide some funding support for research, training, or technological development?

Timing: should the lifting of the Moratorium or the start of O&G development be timed according to BC, American, or Global O&G greatest demand?

Terrorism, protestors, other attacks

- What are the risks?
- Are there preventative measures that can be taken?
- How much does publicity and media attention increase the risk?
- How can negative activity or media attention be redirected in a more positive manner?

Revenue & profits

- What is the best way to apply profits from BC offshore O&G production?
    - medical
    - education
    - technological development to reduce emissions causing global warming

- development and conversion to other fuel technologies less harmful to the environment (e.g. hydrogen fuels, Dr. M. Whiticar, UVic, Nov 2, 2001 presentation)
- engineering to produce safer tankers, pipelines, or platform structures
- others

Presentations

- How much and what type of information, and when should it be presented to the public and others?
- There is a need for a more graphic style of presentation to include many images (figures, charts, maps, etc.) - whether it is in a report, poster, brochure, or seminar. Condense and filter information to the most important issues. Many viewers/readers (most?) would look first at an image, then short text, and lastly a lengthy document.

List of some comments and questions linked to categories in the 2001 Whitford Report

Comments and questions linked to categories in the 2001 Whitford Report			
category	**contents**	**page**	**comments and questions**
Introduction	1.0 & Fig. 1.1	1-2	Map and text should include all BC coastal & offshore wells drilled in the Queen Charlotte, Tofino and Georgia Basins.
Regulatory regime	2.0 to 2.3.6	5-23	Consider developing clear and precise industry guidelines that step through the application and regulatory process (through all Gov't departments). Order the process so that meeting the guidelines is "streamlined" and efficient. No Gov't red tape & delays to industry if the order and guidelines are followed. Give an accurate time estimate to industry for the application review and approval/rejection process.
Regulatory regime	2.0 to 2.3.6	5-23	Be clear on how regulations will be monitored and the monitoring agencies that are involved.
Regulatory regime	2.0 to 2.3.6	5-23	Consider safety regulations regarding rig blow-out, fire, spills, etc. Determine fastest speed of shutdown and what on-site & nearby equipment is available to reduce environmental hazards should an accident happen. Develop prevention & safety regulations.
Regulatory regime	2.0 to 2.3.6	5-23	Develop safety and design regulations to minimize hazardous spills for tanker transport & product transfer. (double-triple hulls?)
Regulatory regime	2.0 to 2.3.6	5-23	Should regulations be developed to keep O&G platforms and tanker/shipping travel away from environmentally sensitive areas?
Marine Coastal Biodiversity	3.1.1.	23	Conway, K.W., Barrie, J.V., and Neuweiler, M. June 2001. Hexactinellid sponge reefs on the Canadian continental shelf: a unique "living fossil". Geoscience Canada, v. 28, no. 2, p. 71-78. Should all or some of the sponge sites referred to in Figure 8 be protected? Are there other sites?

Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	Need more information on marine microorganisms, plankton, benthos, and the algae that are the foundation of the ecosystem - feeding those higher up on the food chain. Need maps and distributions.
Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	More current literature may be available on BC fishes and potential declines from fishing, climate changes, and habitat or food source loss. Present more data?
Marine Coastal Biodiversity	3.1 to 3.2.6	23-29	Need maps and graphics illustrating the distribution of each marine life that may be effected by the O&G industry. It should include habitat and feeding distributions on coastal BC. How much knowledge do we have on BC marine life distributions? There are many marine life topics/issues from microscopic life to mammals.
Marine Coastal Biodiversity	3.2.7	29	Need a map showing existing aquaculture sites. Is the main concern protection of these sites if there was an oil or chemical spill near by? What precautionary measures could be taken to prevent contamination in an emergency/accident situation?
First Nations	3.3 & Fig. 3.1	30-33	Need map(s) and images showing key marine areas of interest to the Coastal First Nations peoples that are traditionally important for food resources, culture, etc. Can these areas be importance rated (critical/continuous, moderate, low/occasional use)? Categories could include intertidal, nearshore, and shelf to open marine. First focus on the Queen Charlotte & Tofino Basins.
First Nations	3.3 & Fig. 3.1	30-33	What is the extent of the "territorial seas of our people" (Deborah Jeffrey, Tsimshian Tribal Counsel, Press Release, May 14, 2001)? On what basis is this claim made? How is this claim/statement interpreted by Gov't?
First Nations	3.3 & Fig. 3.1	30-33	Do we need further research and mapping to show sea level changes over the last 10,000-13,000 (or more) years within Queen Charlotte and Tofino Basins to indicate potential areas that may have been used by First Nations? Some work has been completed by Josenhans, Fedje, Barrie, Conway, & others. Further studies are in progress within the "*Coasts Under Stress Project*" (contacts: Drs. Rosmary Ommer, Chris Barnes, Harold Coward, Univ. Victoria).
First Nations	3.3 & Fig. 3.1	30-33	Are the First Nation's main concerns: oil/chemical spill risk and the effect on marine resources & fishery, cultural changes from industrial development, and tourism? Other issues?
First Nations	3.3 & Fig. 3.1	30-33	What do the First Nations want? (see Chief Gay Reece, Lax Kw'alaams First Nation speech). Proof that there is no or minimal risk from oil/chemical spill or environmental damage? What is the minimum level of risk that is acceptable? What are the priorities to settle land claims and how does this relate to marine resources? What do First Nations want with respect to employment, revenue sharing, role in decision making, and active participation up-front? Where is there room for compromise or negotiation? First Nations participation up-front appears to be very important.
Communities	3.4	33-38	A map & images showing communities/districts would be useful. Also, include Tofino Basin communities.

Communities	3.4	33-38	Include a section with an example community (E.Coast Canada?) that shows changes within the community after introduction of the O&G industry through to decommission. What is at stake for a community? How does the new O&G industry effect original industries & resources? What happens with schools, health & facilities, housing, etc.? Are the human resources there? Jobs and training, retraining? Influx of new residents? Many of these topics are being looked at in the *"Coasts Under Stress Project"* (contacts: Drs. Rosmary Ommer, Chris Barnes, Harold Coward, Univ. Victoria).
Communities	3.4	33-38	How receptive are these communities to change? Is the timing good following a decline in other resource industries?
Other Resource Use: Tourism, sensitive areas, ports, shipping	3.5	38-44	Have there been any studies on the visual effect on tourism of a drilling platform in a "natural" or "marine wildlife" environment? Is the drilling platform a true "eye-sore" or does it provide some curiosity and intrigue - becoming a tourist attraction itself? Can we find an example of a drilling platform off a nature park somewhere in the world? Dr. Chris Barnes (UVic) mentioned to me one that is located off a park in New Zealand. This might be an excellent example especially since it also is in a tectonically active area.
Other Resource Use: Tourism, sensitive areas, ports, shipping	3.5	38-40	Cruise ships also may be considered an "eye-sore". These ships are a large man-made structure that contributes wastes and pollution to the environment in addition to wave wash to the shorelines.
Other Resource Use: Tourism, sensitive areas	3.5.2 to 3.5.3.3	40-44	Need a map & images showing each of the BC marine parks and sensitive areas. Rate areas according to importance/sensitivity. Also, include land and resource management plan areas.
Shipping	3.5.4	44	What statistics does BC have on shipping accidents and environmental damage (especially from large ships)? Would having a Port Authority pilot on each tanker and ship within BC waters improve safety and accident risk? Is shipping of O&G an industry requirement? Can it be achieved safely through an underground pipeline in a tectonically active basin (global examples)?
Physical Environment: Bathymetry	4.1.1	46-48	Canadian Hydrographic charts: how outdated are these charts? Are there dangerous features (for larger ships or pipelines) such as in actively changing areas (Rose Spit? others?) that need to be chart-updated? How important is it to update BC coastal charts? Can a map be created illustrating and rating the need for chart updates especially in areas of interest for O&G exploration?
Water level & ocean currents	4.3	50-53	Do BC waters demonstrate any more severe tidal and current conditions than other O&G structure locations in the world? What is the worst tide & current scenario for BC coastal waters?
Ocean currents, waves, wind	4.4	54-59	How much additional research is needed to better understand ocean currents and where an oil spill (or other contaminant) may travel should an accidental occur? How important is it to have knowledge on ocean currents for winter months? Is it possible to collect ocean current data during winter months? Is a contaminant spill in winter/storm months less damaging? (Does it disperse faster in greater wave action?)

Weather forecasting	4.4.4	59-62	Confirm that a 6 hour weather warning is sufficient to shut-down & lock-up a rig/platform in preparation for a storm. What is the minimum time for secure shutdown?
Gas Hydrates	4.5	62	Additional references (G. Spence, UVic)? What is the potential resource estimate of gas hydrates in offshore BC? Need a map illustrating gas hydrate locations.
Faulting & earthquakes	4.6	62-64	Recent literature updates on faulting, etc. Rohr & others (1992, 1995, 1997, 1999, 2000). Contact K. Rohr at UVic.
Faulting & earthquakes	4.6	62-64	Can a platform be built to withstand a magnitude 9-10 earthquake and associated ground motion and acceleration? Need map showing ground & motion acceleration.
Faulting & earthquakes	4.6	62-64	Will BC offshore oil and gas extraction add or contribute a significant earthquake risk to the area? In other areas, there have been recorded earthquakes(up to M4.3) that may have resulted from hydrocarbon extraction, high pressure fluid injection, and/or subsidence.
Tsunamis	4.6.2	65	Need map showing areas where there would be tsunami wave amplification or dangers.
Geotechnical hazard areas	4.7	65-66	Need a map & images showing areas of sedimentological hazards (liquefaction, submarine slope instability, sediment gas, etc.) or where future studies need to be made to obtain data.
Sub-sea noise	table 5.1	79	A good table. Has any more current research or data been compiled in the 1990's?
Drilling Technology	5.2	80-90	What are BC offshore well site limitations? Is horizontal drilling a strategic option for the available resource? Can a well site be strategically placed away from an environmentally sensitive area and at what cost?
wastes & disposal	5.2	88-90	Where would sites for disposal of wastes, chemicals, hazardous materials, drilling mud, waters, etc. be located? How would it be monitored? How would fumes be filtered?
Blowout	5.4.3	95-96	If the largest USA offshore blowout was 11,500 barrels in 1988, can an appropriate and immediate spill containment apparatus be regulated/required for each platform (i.e. stored at the site or very close by)? What extra expenses would be necessary to have the equipment/supplies? Is it within an industry budget?
platform collapse or pipeline break			Need more details on the scenarios of platform collapse such as from an earthquake, tsunami, or storm and a pipeline break. What is the maximum chemical or fuel spill and how much environmental damage would follow? What would be the expected expense to industry, Government, others?
Atmospheric emissions	6.1.5; table 6.1	107-109	How do the amount of emissions from an O&G platform compare to other polluting sources (e.g. pulp & paper mill; Robert's Bank Port; BC Ferries (include vehicles); one day of Vancouver cars; etc.)?
pollutants	general		Perhaps one large table could be made including above and other pollutants to compare data from other industrial sites (BC & other?). It would be useful to have comparative data from other industries in Coastal BC.
seismic surveys	6.1.8	110-113	Need maps indicating the timing and distributions of Basin fishes, mammals & other marine creatures that would be most affected by seismic surveys.

seismic surveys versus drilling			At what level do seismic surveys stop and drilling begins? How extensive are gassy sediments in the BC offshore basins and how much do they limit the value of seismic surveys from "seeing through the "frosted glass window"? Have new technologies been developed to better filter and understand data in gas rich sediments? Would there be better value in drilling more exploratory/test holes?
geological resources			Need knowledge and maps on the location of mine/quarry resources (gravels, lime, other) and industry requirements for resource transportation.
Archival information			What information is available in the BC archives (or other) on previous BC offshore exploration and drilling? Are there any photos? Were there any accidents or spills? What was the equipment and worker resource? What communities were involved? What was the media and public response to these activities at that time?

List of initial maps and images which could be used to build a reference or atlas on BC offshore oil and gas development and environment.

BC Offshore Oil and Gas Development and Environment Atlas	
Topic	**contents & comments**
outline coastal BC & Can/USA borders	base map
land topography, rivers, lakes, etc.	base map
communities to cities, airports, port facilities, lighthouses, railways, etc.	maps and images - especially those relevant to O&G development
shipping/boating	map and images showing current typical shipping & boat use patterns/areas (e.g. tankers, cruise liners, cargo, lumber industry, fishing, pleasure, etc.). This shows current use and a certain level of risk for contaminent spills or other hazards.
parks & other environment designated areas	maps and images
First Nation's communities & reserves	Map 1: existing and past communites, Map 2: desired land claims; Map 3: land and marine areas/regions used by First Nations. Images showing nearshore and marine resource use.
weather	one or more maps & images showing weather patterns (including storms, seasons, and patterns such as El Nino)
marine bathymetry	maps and images that indicate areas of rapid change (e.g. Rose Spit erosion & transport, etc., areas of frequent slides/slumps, etc.)
tsunami hazard map	map indicating areas most sensitive to tsunami wave amplification
marine charts	subdivide into regions as per need of upgrade (may be based on year, urgency for upgrade such as seafloor change, or increased use assocated with O&G exploration or expected production).
geology of QCI & Vanc. Is. & coastal regions	overview geological maps & images

oil & gas basins/resource potential	Include previously drilled wells and those that may be target by industry in future. Provide some archival photos.
faults	indicate all known faults that may effect O&G industry
seismic surveys	showing all previous seismic surveys (or most important ones); Include relevant seismic data/results.
earthquake hazard	map showing magnitude & position of previous earthquakes (>M2.5?). Include hazard map.
marine geology	basin structure 1) understand stability for installation of drilling platform, underground pipelines, etc.; 2) geology for locating O&G; 3) location of possible in situ gas
marine surveys	showing core locations (e.g. GSC) that may provide data for future studies, show possible future sites
geological materials	source of gravels & other materials necessary for industry
aeromagnetic surveys	available data
sea level change to 13,000 years ago	Within the basins, provide maps showing past sea level drops that may have been significant to First Nation's peoples for travel across the region. Do they have a claim to these past lands now covered by marine waters?
ocean currents & hazards	several maps showing critical regions & timing; several model maps showing if there was an oil spill -where the oil would be transported.
oceanography	several maps showing marine temperature gradients, salinity, pressure, anoxia or other special conditions, etc.
Biology/ecology	multiple maps indicating critical/high use regions for each form of life from plankton to mammals (including marine plants) that may be effected by the O&G industry.
Biology/ecology cont.	Examples: plankton & micro-benthics, sponges, shellfish, other invertebrates, algae, fishes, birds, marine mammals (whales & dolphins, seals, otters, etc.) & others. Multiple species & genera may be involved.
Oil & Gas technology	Showing equipment and structures through various phases of design and building, exploration, development, production, and decommissioning. Compare to first drilling in offshore BC?

Appendix 14: Oceanographic Situation of Hecate Strait, BC[12]

Introduction

The Hecate Strait is situated between the BC mainland and the Queen Charlotte Islands centered around 53°N latitude and 131°W longitude (Figure 1). Although the Hecate Strait is somewhat protected from the Pacific Ocean by the Queen Charlotte Islands, the size of the water body (55 km to 120 km wide), its morphology and oceanographic and weather situation make it susceptible to severe conditions. The Dixon Entrance to the north and Queen Charlotte Sound to the south of Hecate Strait have oceanographic conditions somewhat different from the Hecate Strait.

Bathymetry

Figure 1 shows the water depth isobaths for the region. The majority of the Hecate Strait has relatively shallow water depths of 200m or less, and reaches up to 300m deep in the south. Much of the Queen Charlotte Sound is also shallower than 200m but reaches 400m in the troughs. The Dixon Entrance shallows from 400m to 200m landward, with the exception of the 35 m Learmonth Bank at the mouth of the Dixon Entrance.

The water depths in the Hecate Strait and Queen Charlotte Sound are commonly encountered in offshore petroleum exploration settings. As such, they do not present any technological restriction on the exploration for petroleum. For comparison with the east coast (Jeanne d'Arc Basin), the discovery well Chevron et al Hibernia P-15 (location: 46°44' 59"N, 48°46'51"W) was drilled by the Glomar Atlantic/Zapata Ugland from May 27,1979 to January 2, 1980 to a Total Depth of 4407m in 80m water depth. In the same Jeanne d'Arc Basin, the discovery well Husky/Bow Valley et al Whiterose N-22 (location: 46°51'48"N, 48°03'57"W; June 27, 1984 - January 4, 1985) was drilled to 4628m in 122m water depth.

Basically the morphology of the Hecate Strait is a shallow, broad shoal in the north with deeper troughs cutting channels along the mainland and towards the Queen Charlotte Sound. Three major troughs characterize the southern part of Hecate Strait and Queen Charlotte Sound as seen in Figure 1. The most northerly of the three traverses between the southern tip of Moresby Island and Middle Bank. The second trough cuts between Middle Bank and Goose Bank and the third trough is between Goose and Cook Banks.

On the western margin of the Queen Charlotte Islands, the shelf is very narrow; approximately 40 km in the north and 10 km to the south. Further west, the Pacific Ocean deepens rapidly to >2,500 m.

[12] Submission to Dr. D. S. Strong, Chair, Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Dr. Michael J. Whiticar, School of Earth and Ocean Sciences, University of Victoria, BC December, 2001.

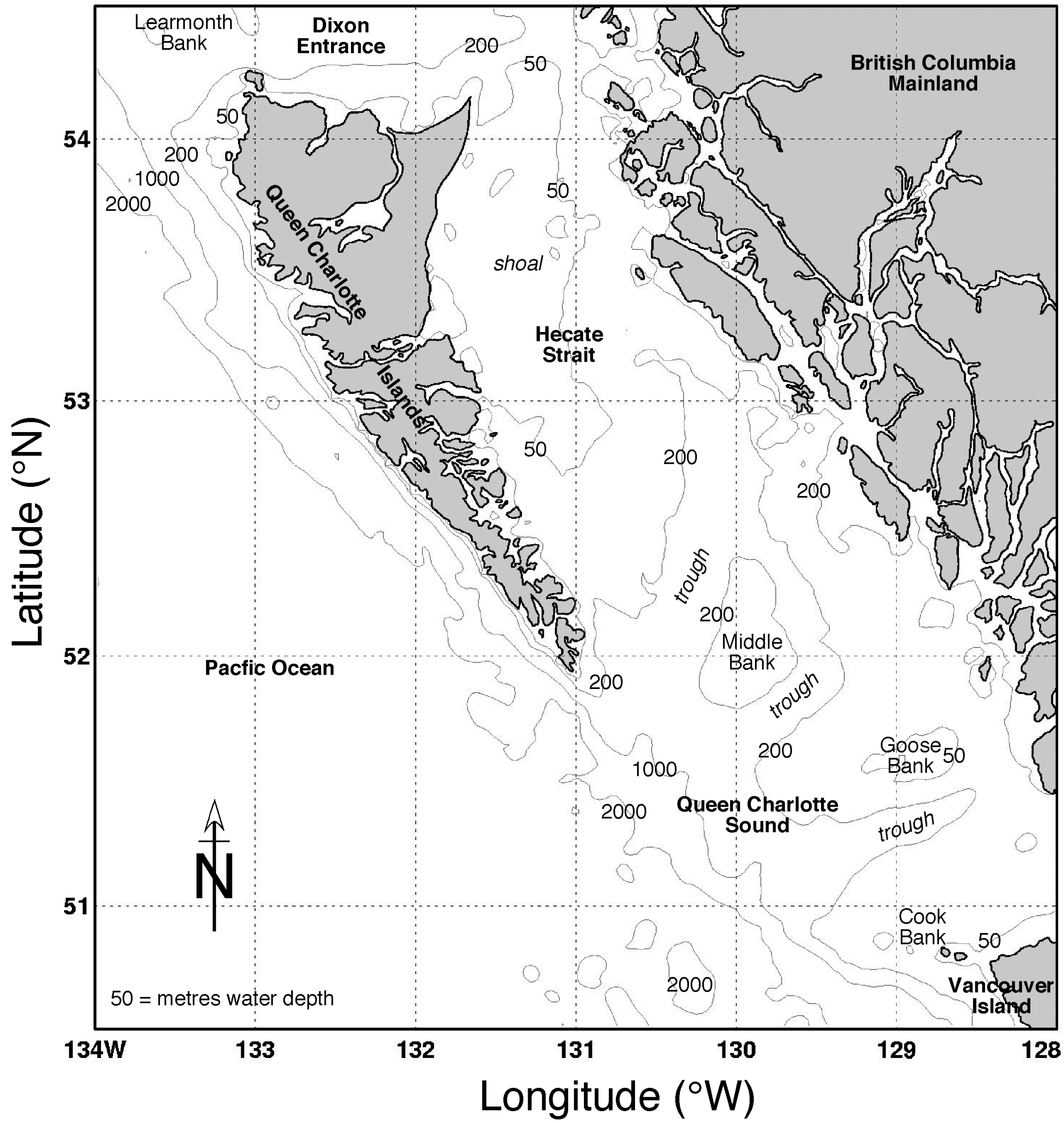

Figure 1. Location map of Hecate Strait (Queen Charlotte Basin) showing the basic bathymetry (modified from W. R. Crawford, IOS-DFO)

Climate, Weather and Winds

The climate of the Hecate Strait can be characterized as a temperate climate with a strong westerly onflow of moist marine air. It is one of the areas of Canada with the strongest winds. Values of up to 200 km/hr have been recorded (Cape St. James). Due to topographic highs created by the coastal mountains, the winds tend to blow north and south along the axis of Hecate Strait. These winds are driven by seasonally changing surface ocean temperatures and barometric pressure systems. As discussed in detail below, the surface water temperatures in Hecate Strait can vary from 8 – 16°C in the summer to 4 – 9°C in the winter.

The air temperatures taken continuously over the past 50 years in the region display a much larger range that the water temperatures. For example, typical air temperatures on land in Massett are 18°C in the summer and 4°C in the winter. Average air temperatures over the water in the area seasonally vary about 9°C, with a mean temperature of 12°C in July and 3°C in January.

Despite the apparent mild temperatures, annually there are approximately 20 frost days in the region. The freezing and icing associated with this is recognized as a particular hazard of operations in the region, but do not pose any unusual conditions to those encountered in similar higher latitude onshore and offshore exploration and production operations elsewhere in BC, Canada and internationally.

For example in the Jeanne d'Arc Basin on the east coast (Grand Banks region), the temperature variations are larger and more severe. There the air temperature ranges from –17.3°C to 26.5°C, the surface water temperature ranges from –1.7°C to 15.4°C. In the Jeanne d'Arc Basin the thickness of icing (glaze and rime) is 72 mm (10 year maximum) to 169 mm (100 year maximum). Similarly, spray icing thickness in the region is 316 mm (10 year maximum) and 514 mm (100 year maximum).

Furthermore, there is a considerable number of iceberg sightings in the Jeanne d'Arc Basin area of operations (annual mean: 72, maximum: 169 on a one-degree grid).

The two barometric pressure systems are the North Pacific High and the Aleutian Low. The former dominates in the summer and generates northerly winds (ca. 30 km/h). The Aleutian Low is dominant in the winter months and creates southerly winds (ca. 50 km/h). Winds are strongest from October to February and are usually out of the south or southeast.

Month	Nov	Dec	Jan	Feb	Mar
Average Wind Velocity (km/h)	34	37	39	40	38
Highest Recorded Gust (km/h)	191	181	191	189	193

In comparison, the winds in the Jeanne d'Arc Basin on have 1-hour maxima of 120 – 157 km/h and 1-minute maxima of 139 – 167 km/h.

Rainfall in the region is also high with a considerable range from 80 on the eastern coast of Queen Charlotte Island to 400 cm/yr on the west coast. In Massett, the precipitation is ca. 100 cm/yr as rainfall and ca. 28 cm/yr as snowfall.

	Sandspit Airport	Cape Saint James
Average Rainfall (cm/yr)	135	154
Average Temperature (°C)	8.1	8.7

The weather is monitored by a system of land-based stations operated by the Meteorological Service of Canada, marine weather buoys by DFO and from the MAREP station.

Tides, Currents and Waves

The Hecate Strait has two diurnal tides. The tidal range is smaller in the south (ca. 3 m) and increases to ca. 5 m in the central and north Hecate Strait. Some coastal regions have higher tidal ranges, e.g., up to 7 m at Prince Rupert. For comparison, the tides in the Jeanne d'Arc Basin region are significantly lower (ca. 0.5m above and below mean sealevel). Storm surges in this Grand Banks region do not contribute to significant tidal variations.

Currents in the Hecate Strait are driven by tidal forcing and by prevailing winds. Some coastal effects can also influence the local currents. Figure 2 shows the current directions and strengths for the Dixon Entrance, Hecate Strait and Queen Charlotte Sound during flood and ebb phases. During flood the water flows into Hecate Strait from the Dixon Entrance and Queen Charlotte Sound. During ebb, the situation is largely reversed. Typical surface current speeds are 25 – 50 cm/s (equivalent to 0.5 – 1 knot).

Local variations do occur, especially associated with land constrictions. For example, Figure 3 shows tidal currents up to 250 cm/s flowing around Cape St. James on the south tip of the Queen Charlotte Islands.

The bottom currents are somewhat lower, with typical values at 15 – 25 cm/s.

Wind-driven currents are less important than the tidal currents, but during intense storms wind-shear surface currents can attain values up to 25 cm/s.

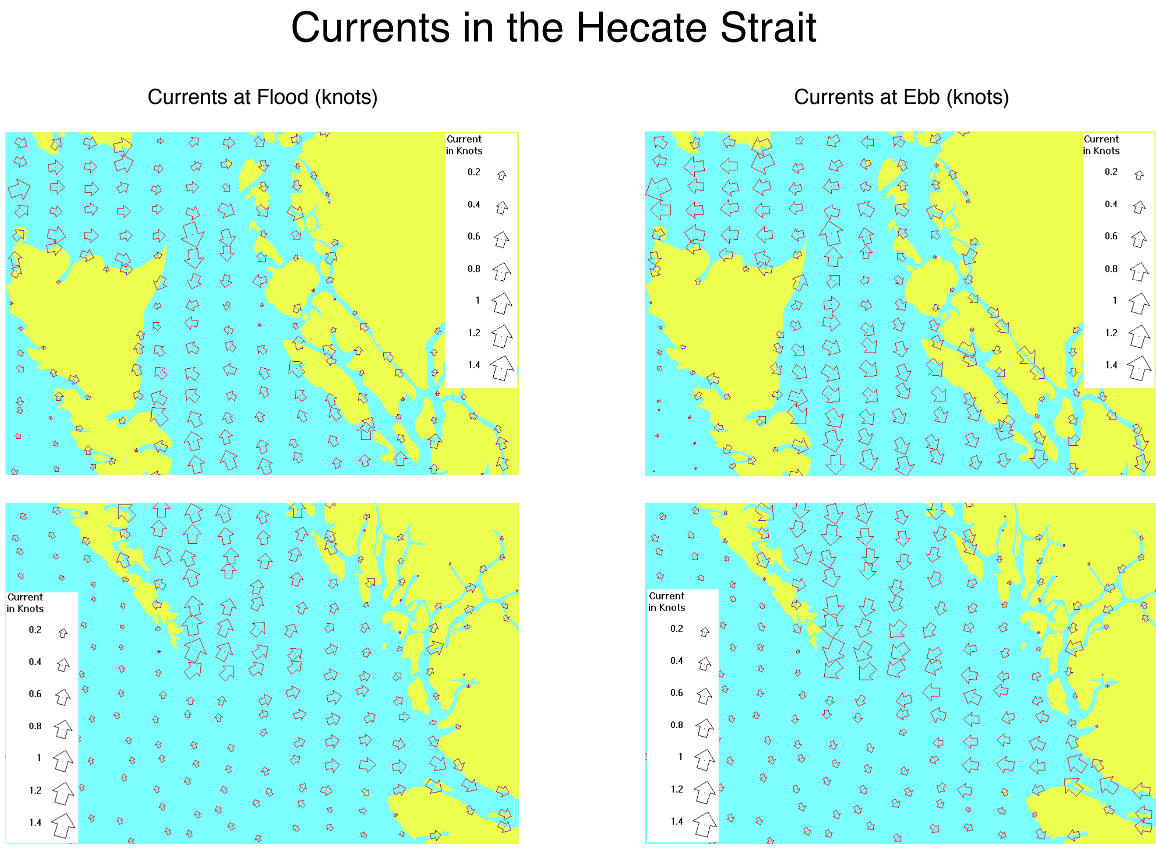

Figure 2. Currents in Hecate Strait (from R. Thomson, IOS-DFO)

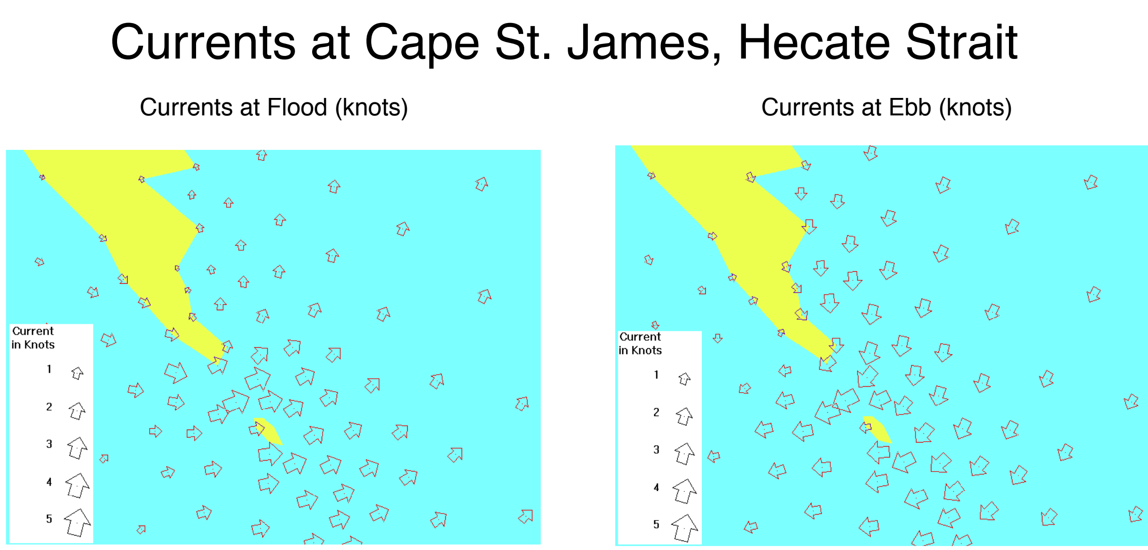

Figure 3. Currents at Cape St. James, Hecate Strait (from R. Thomson, IOS-DFO)

In comparison, the currents in the Jeanne d'Arc Basin are somewhat lower than the Hecate Strait. In the Jeanne d'Arc Basin the surface currents are 7.5 – 8.0 cm/s at the surface (10m, 1 – 10 year period) and a 100 year maximum of 10 cm/s. In mid-water (25m and 75m) the currents are 6.0 – 7.6 cm/s and 3.0 – 6.0 cm/s, respectively. The corresponding 100 year maximum for these two water depths is 9.5 and 7.5 cm/s. At the sea floor (ca. 100m) the 1 – 10 year period currents are 1.5 – 3.2 cm/s and a 100 year maximum of 6.5 cm/s.

A series IOS, DFO current moorings are deployed in the region as shown in Figure 4. Together with IOS drifter studies, e.g. Figures 5 and 6, the surface currents are well studied in the petroleum exploration regions of Hecate Strait and the Queen Charlotte Sound. However, more site-specific bottom current studies are required.

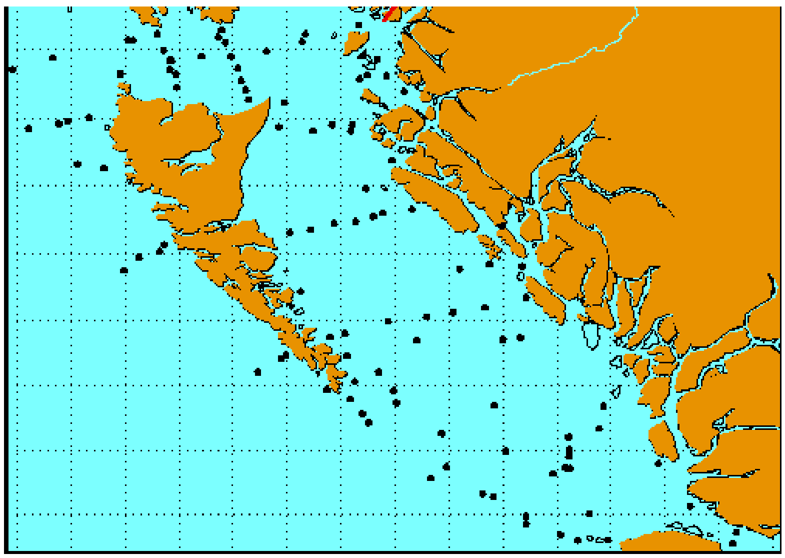

Figure 4. Current mooring stations around Queen Charlotte Islands (from R. Thomson, IOS-DFO)

The strong winds in the Hecate Strait generate considerable waves and swells. The actual wave heights are dependent on the fetch, i.e., the proximity to sheltering land, and on the water depth. Pacific Ocean swells influence much of the lower part of Hecate Strait and the Queen Charlotte Sound. During storm events the sea state can increase to over 10 m. Waves of 20 – 30 m have been recorded in the strait. Of particular concern is the rapidity with which the seas can increase, often within hours.

Wave heights in the Jeanne d'Arc Basin, which has experienced substantial exploration and production activities, are very similar to the Hecate Strait. In the Jeanne d'Arc Basin the significant wave height is 11 – 14 m (1 – 10 year report), and a 100-year value of 17.5m. The corresponding maximum wave heights are 20.9 – 30.4m (1 – 10 year) and 30.4m (100-year).

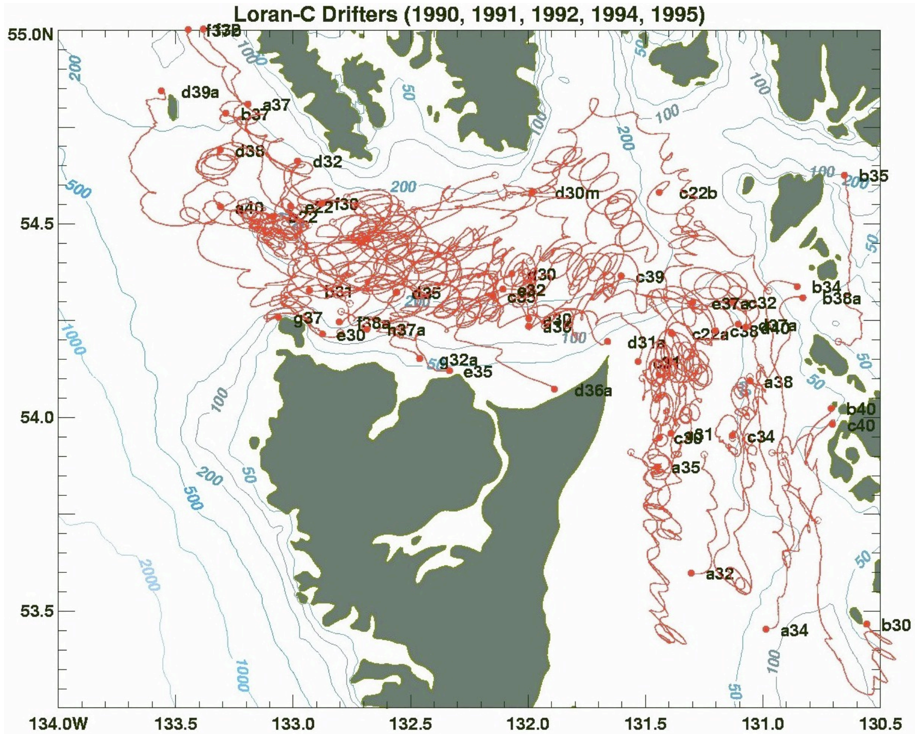

Figure 5. Example of current drifter tracks in Dixon Entrance and northern Hecate Strait (from R. Thomson, IOS-DFO)

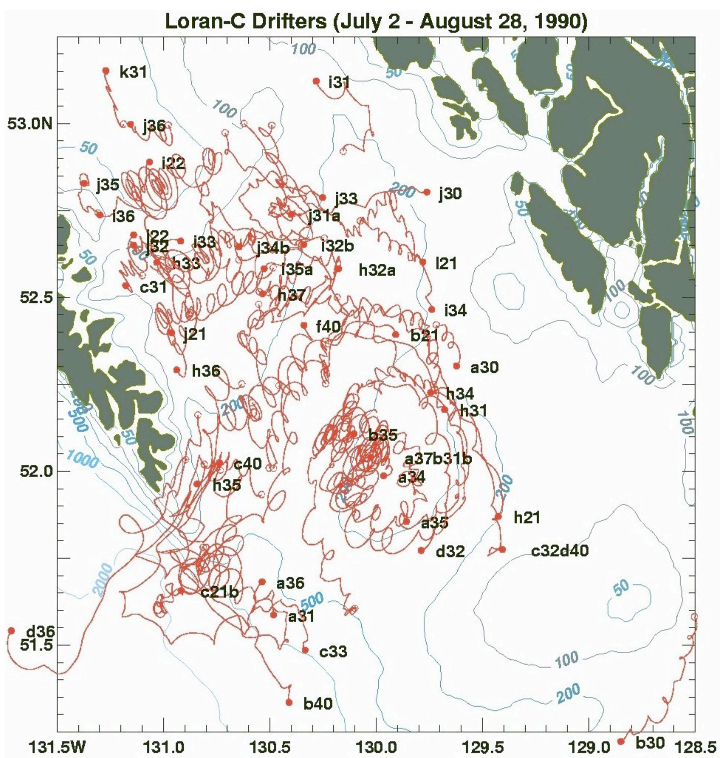

Figure 6. Example of current drifter tracks in southern Hecate Strait and northern Queen Charlotte Sound (from R. Thomson, IOS-DFO)

Water Temperature

The water temperature depth structure in Hecate Strait have been observed during cruises to the region by the DFO Institute of Ocean Sciences. Figure 7, is a generalized depth plot of the water temperature in the Hecate Strait and Queen Charlotte Sound (data from W.R. Crawford, DFO, IOS). Below the uppermost 50m the temperature varies little between 4 and 8°C. Actual variations at a specific locality can have even less range. The local temperature depth distributions (3, 50, 100, 200m and bottom water) is shown in the vertical series isotherm maps (contours of equal temperature) for the region (Figures 8 and 9).

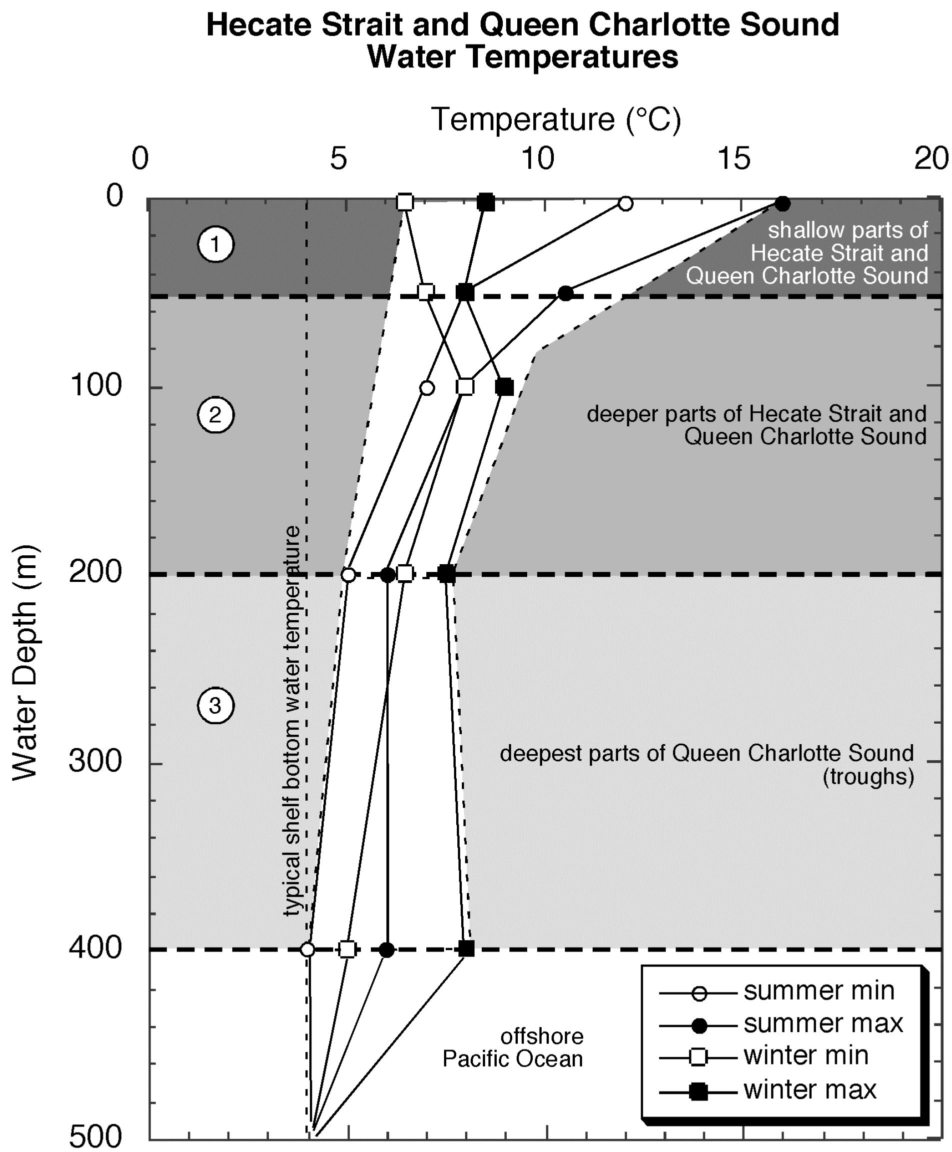

Figure 7. Water temperature profiles (maximum and minimum temperatures) for summer and winter months (data W.R. Crawford, DFO, IOS)

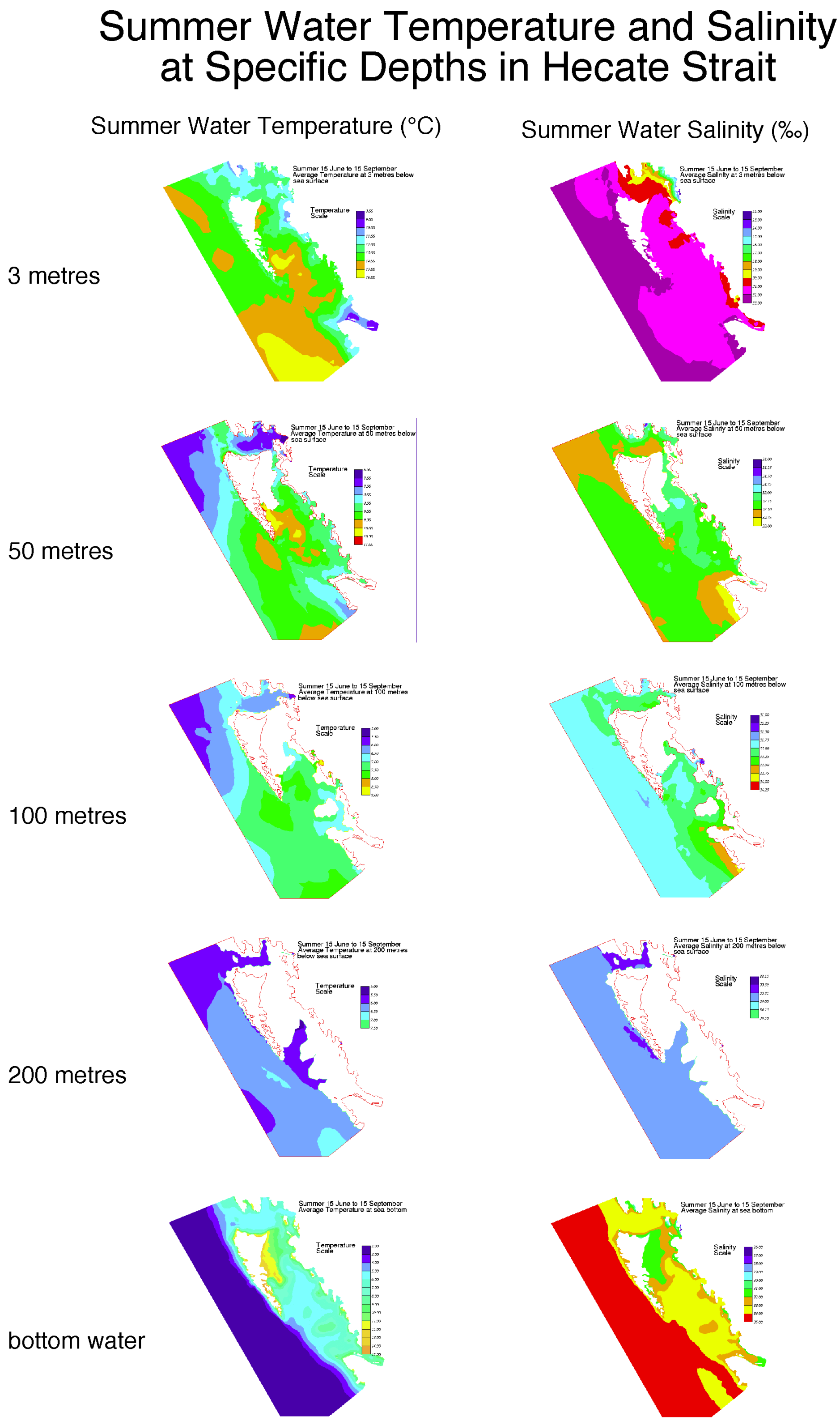

Figure 8. Summer temperature and salinity contour maps at selected depths in Hecate Strait and Queen Charlotte Sound (data W.R. Crawford, DFO-IOS)

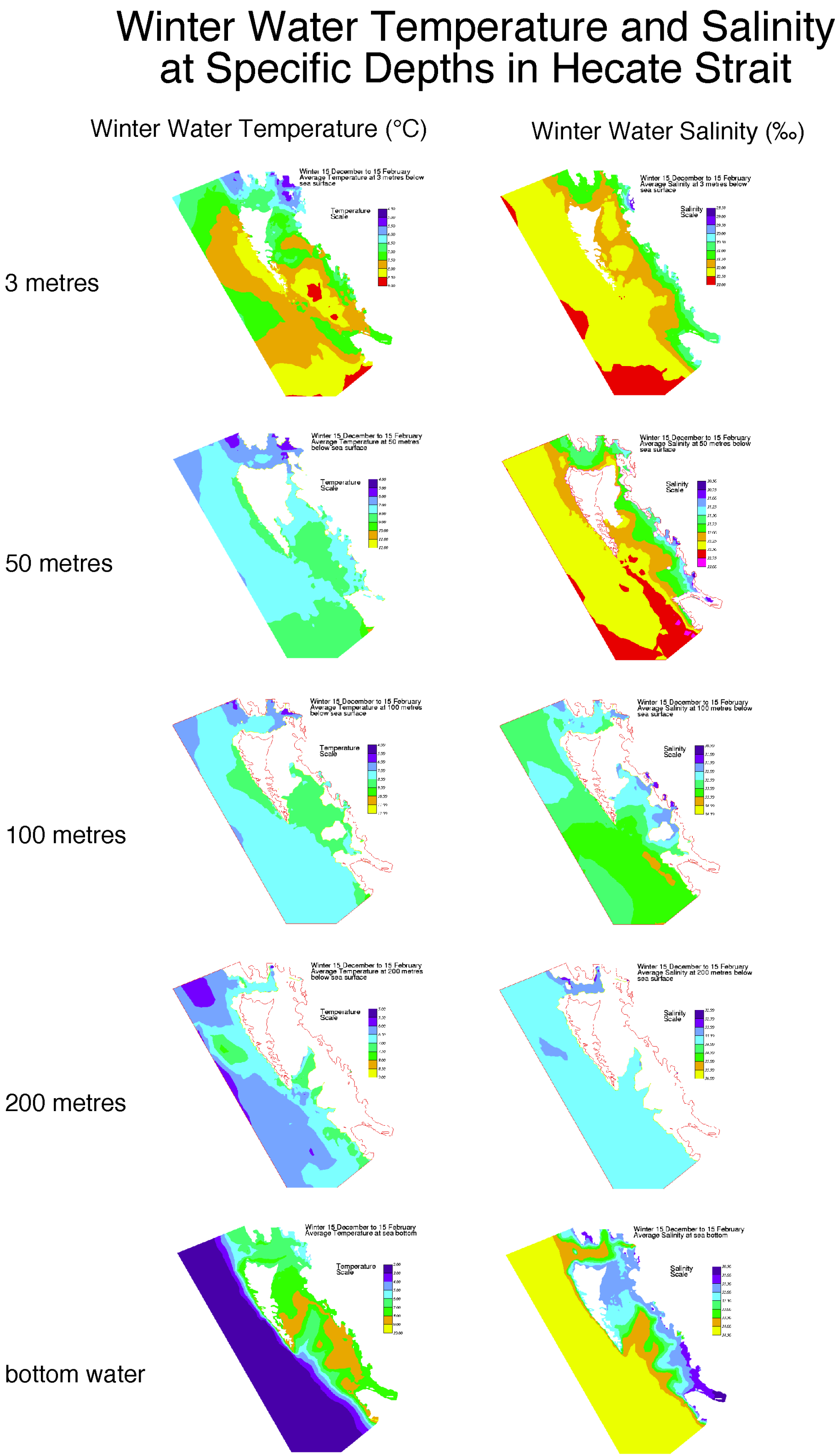

Figure 9. Winter temperature and salinity contour maps at selected depths in Hecate Strait and Queen Charlotte Sound (data W.R. Crawford, DFO-IOS)

Regionally the water temperatures can vary from 8 – 16°C in the summer to 4 – 9°C in the winter, with most of the range in the surface waters that vary from 6 – 16°C (Figure 7). These relatively mild and constant water temperatures strongly moderate the regional climate.

In comparison on the east coast in the Jeanne d'Arc Basin (Grand Banks region), the temperature variations are larger and much more severe. There the air temperature ranges from –17.3°C to 26.5°C, the surface water temperature ranges from –1.7°C to 15.4°C and the sea bottom temperature ranges from –1.7°C to 3.0°C.

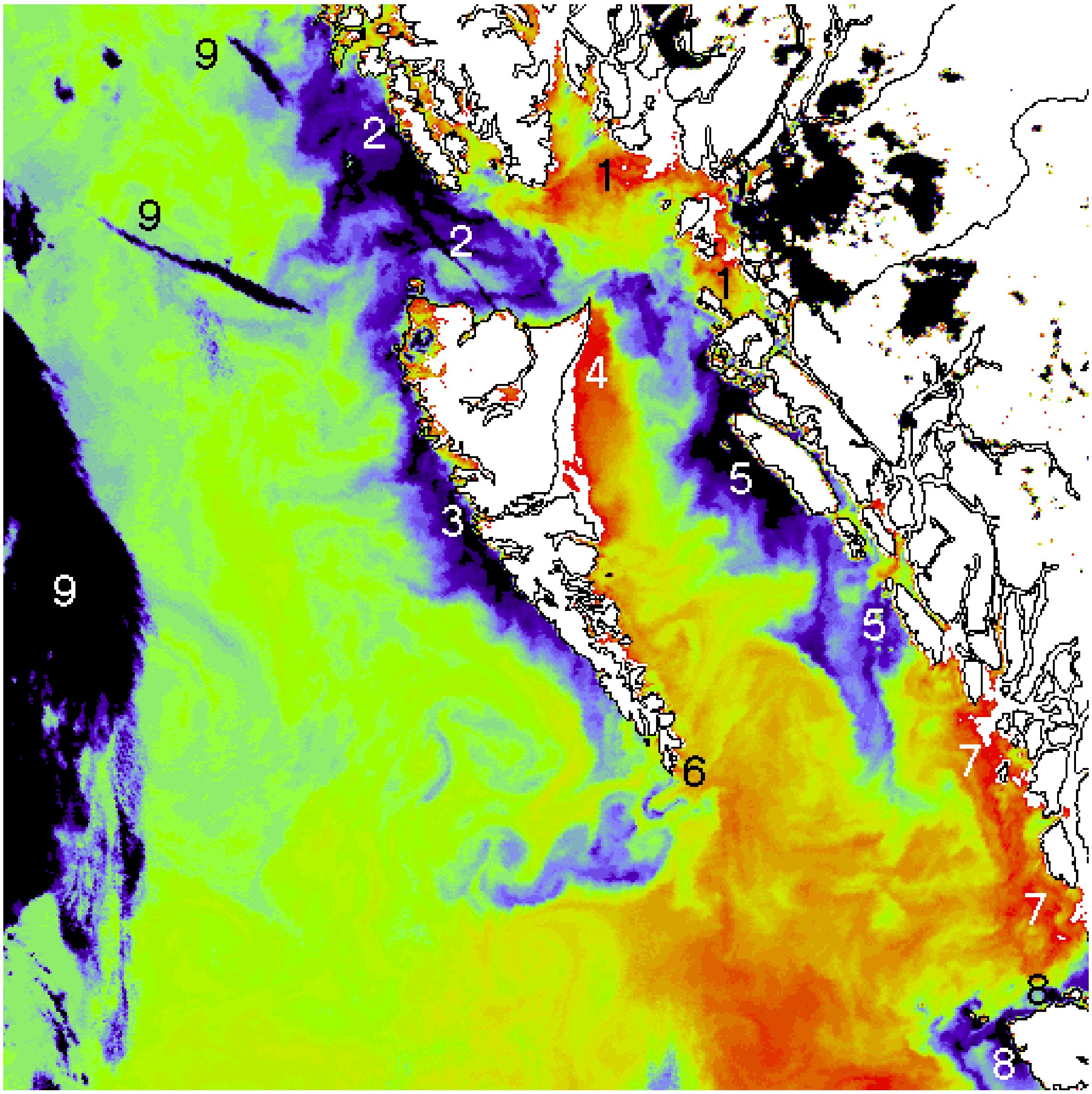

Figure 10. Summer surface water temperature (after Gower and Wallace, 2001) Cool water (10°C appears blue, warmer waters are in red, ca. 16 °C).

Figure 10, from Gower and Wallace (2001) shows a US National Atmospheric and Oceanic Administration (NOAA) satellite image of the summer surface water temperature in the Queen Charlotte Island region (24 July 1994, near 6:00 Pacific Daylight Time. The cooler temperatures (ca. 10°C) plot as dark areas in the figure whereas the warmer regions (16°C) plot as lighter areas. At the time, the winds were from the northwest. The numbers indicated in the figure correspond to the areas of local interpretation by Gower and Wallace (2001). For information purposes their interpretations are cited verbatim below.

[1] Chatham Sound and Skeena River Plume in Northern Dixon Entrance

Fresh water from the Skeena River mixes with salt water in Chatham Sound, and flows out of Chatham Sound as a five metre deep layer of brackish water. Sediments in this water absorb light, which warms this layer as it flows northward out of the Sound, then westward across Dixon Entrance. Any brackish water that flows out of Chatham Sound through channels to the west passes through narrow channels with strong tidal currents that mix deep cold water up to the surface, and cool this layer.

[2] Western Dixon Entrance and the Southern Alaskan Panhandle

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from Alaskan shores. This waters are replaced at shore by colder deep water that upwells to the surface, and is blown into Dixon Entrance when the northwest winds are especially strong.

[3] West Coast Queen Charlotte Islands

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from west coast of the Queen Charlotte Islands. Waters that move away from the coast are replaced at the ocean surface by deeper colder water all along the west coast of Graham Island and much of Moresby Island.

[4] Dogfish Banks

Waters here are generally 10 to 20 metres deep, much less than in other areas, and are also the warmest in summer.

[5] Eastern of Hecate Strait

Summer winds generally blow from the northwest in this region, pushing the surface waters downwind. The effect of the rotation of the earth is to turn these currents to the right, away from the mainland side of Hecate Strait. Waters that move away from the coast are replaced at the ocean surface by deeper colder water all along the coast, as far south as the southern end of Aristazabel Island.

[6] Cape St. James, south end of Moresby Island

Strong tidal currents are found at the southern tip of Moresby Island, within a few kilometres of Cape St. James and the Kerouard Islands, where speeds as high as 5 knots are found. In summer the winds from the northwest push the warm surface waters of Hecate Strait southward past Cape St. James and into the open Pacific Ocean. Tidal currents at this cape bring deep cold water to the surface where they partially mix with warmer surface water. All these water masses flow about 100 kilometres southwestward into the Pacific Ocean, forming a distinctive plume in this image.

[7] Eastern Queen Charlotte Sound

On this day the fresh water from Rivers Inlet was in a layer only a few metres thick along the eastern shores of Queen Charlotte Sound. It soaked up heat from the sun as it gradually drifted into Queen Charlotte Sound

[8] Cape Scott and Cook Bank at north end of Vancouver Island

Strong tidal currents on Cook Bank and near Cape Scott mix cold deep waters into warm surface flows. The winds from the northwest push these waters up against the shore, and they then squirt westward into the Pacific Ocean and also to the southeast along the west coast of Vancouver Island.

[9] Clouds West of Graham Island

Clouds west of Graham Island appear black, as do the jet contrails to the Northwest of Graham Island.

Water Salinity

The salinity of the in Hecate Strait and Queen Charlotte Sound, based on data from W.R. Crawford, DFO-IOS, ranges from 30 ‰ to 34‰. Figure 11 shows a depth plot of the salinity in the region. As expected, the surface waters show the greatest variability, and tend to have the lower values (30 – 32.5‰). This is due to several factors, including runoff of fresh water from land, sea surface evaporation, and downwelling, upwelling and lateral mixing. The deeper waters are more homogeneous and converge on an ocean salinity value of 34‰.

Mapping of the isohalines (contours of equal salinity) for different depths in the region (3, 50, 100, 200 m and bottom water) are shown in Figure 8 for the summer months and Figure 9 for the winter months. Again, it is clear that the greatest variations in salinity are observed in the coastal and shallower waters.

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Appendix 15: Potential Interactions Between Oil and Gas Exploration and Development and Living Marine Resources in the Queen Charlotte Basin Area[13]

ISSUE:

There is an aspiration to explore and develop the potentially valuable oil and gas resources in the Queen Charlotte Basin. The concern is that oil and gas exploration and development might adversely impact on sustainability and value of the marine fish, plants, mammals and birds, their habitat, harvests and use. This paper provides an overview of some scientific considerations of possible impacts on living resources that could result from oil and gas exploration, development and production.

AREA OF INTEREST:

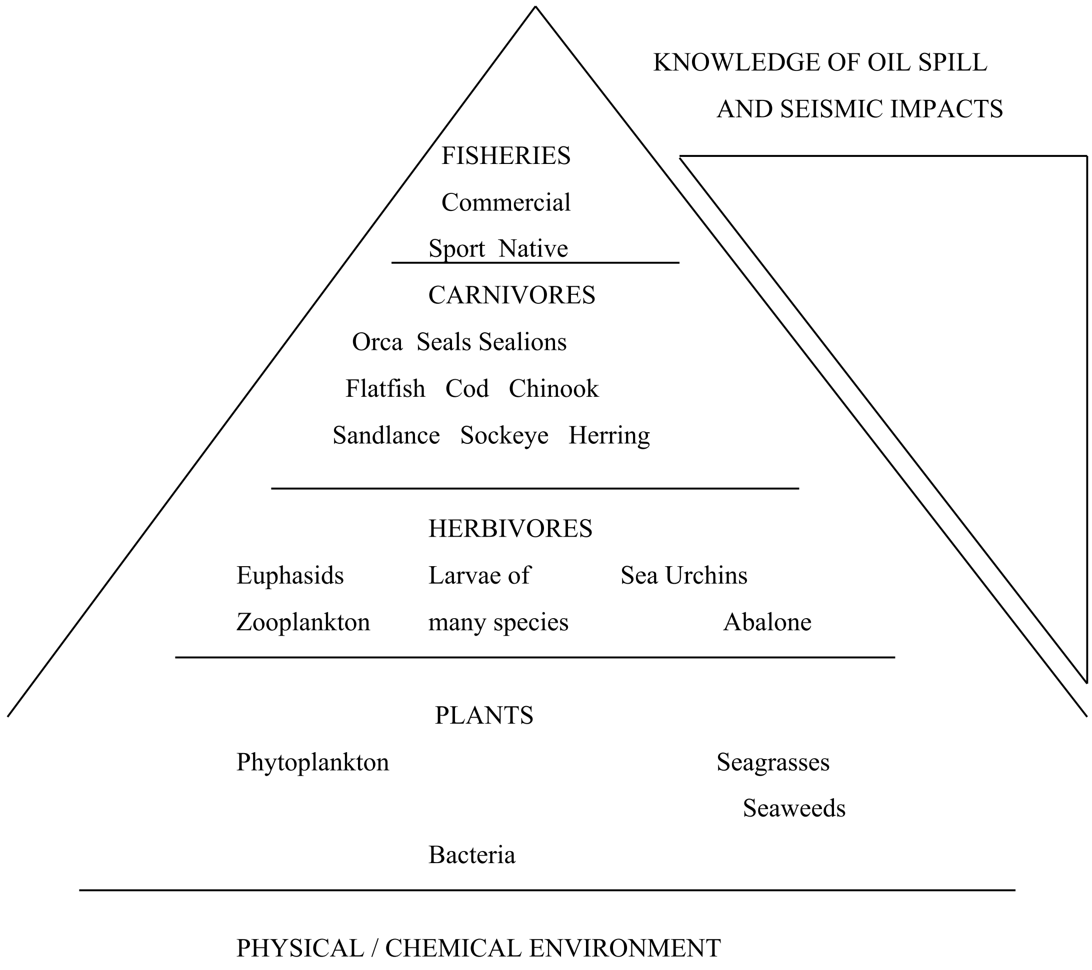
The area of interest for oil and gas exploration and potential development is known as the Queen Charlotte Basin - from the north end of Vancouver Island to the border with Alaska and from exclusion zones, 20km seaward from any point of land. The highest oil and gas potential is thought to be in the Queen Charlotte Islands portion of this area.

ECOLOGICAL PYRAMID:

The following ecological pyramid represents an ecosystem in which the individual species interact. Each layer in the pyramid is dependent on the layers below it and is impacted by those above. The lower in the pyramid an impact occurs, the greater the overall impact on the ecosystem is likely to be and the more difficult it will be to demonstrate the impact on human harvest. For example, reductions in phytoplankton or zooplankton would impact most carnivores and human harvest. The recent downturn in production of many marine fish, bird and mammal species is attributed to decreased phytoplankton and zooplankton production resulting from adverse ocean conditions.

[13] Submission to Dr. Patricia Gallaugher, Member – BC Offshore Hydrocarbon Development Scientific Review Panel, prepared by Allen Wood Consulting Inc. January 7, 2002.

ECOLOGICAL PYRAMID



Most knowledge of oil and gas exploration and development impacts is related to accessible species in the intertidal area and to commercially valuable species. Although phytoplankton and planktonic herbivores directly or indirectly feed the majority of the ecosystem, there is little information on oil impacts on either. Also, most assessment has been of impacts on single species, rarely on the ecosystem. However, the impacts of ripple effects through the ecosystem are likely to be significant. A major decrease in prey species could result in a decrease in a species of interest, but because of the high natural variability of many species, cause and effect is often difficult to demonstrate.

The layers of the ecological pyramid include:

1. PHYSICAL/CHEMICAL ENVIRONMENT: Changes in the physical and chemical environment and toxic substances added to the environment by exploration, development or accidents are concerns at this level.

2. BACTERIA: “Despite their importance to ecosystem restoration, studies on role of marine bacteria in post-spill situations has been minimal.” (Sloan, 1999). There is very limited work on negative impacts on bacteria.

3. PLANTS

Phytoplankton: There have been a number of studies on the effects of oil on phytoplankton using large enclosures. They found that “oil could be lethal or reduce photosynthesis and growth of phytoplankton, and, at low concentrations, stimulate phytoplankton growth." (Sloan, 1999). Impacts are dependent on the species, season, local conditions and the oil amount and type. There is limited and conflicting evidence on long-term impacts of oil on phytoplankton.

Seaweeds: Intertidal seaweeds generally are more exposed to oil deposition and residence than those in subtidal areas. As intertidal seaweeds are more accessible for observation, there is more information about impacts on them. Multicellular algae often have alternating life phases with different susceptibilities to oil, but there is little information on the gametophyte stage. Oil impacts and recovery rates differ between species, season, local conditions and the oil amount and type. Remedial cleanup actions also can have severe impact on seaweeds and on associated communities. Subtidal and low intertidal seaweeds have been observed to show increased growth due to oil death of herbivores that feed on them.

Seagrass: Portions of seagrass exposed to oil perished while subtidal portions survived. Seagrasses are killed by smothering, poisoning, and habitat destruction. Sublethal effects of oil can lower tolerance to other stresses. Tainting and loss of seagrasses affects dependent food and habitat webs.

Coastal Wetlands: Salt marsh plants are highly susceptible to chronic oil pollution, in part because oil is not washed off plants by wave action. Oil impacts these highly productive areas for a number of years (more than 6), depending on the amount and type of oil, plant species, season and local conditions.

4. HERBIVORES

Zooplankton: Oil effects on zooplankton are greatest at the water surface and in enclosed inshore areas. Zooplankton, such as euphasids, are the key food of most fish at some stage in their life. Many species contain high levels of natural oils in their eggs or over-wintering cysts as energy stores, so it is possible that they could incorporate petroleum (Reid, 1987). This oil could be transferred to their predators.

Grazing herbivores such as sea urchins, and probably abalone, limpets, chitons, and snails, are highly impacted by oil. Organisms in intertidal areas are much more affected than those in subtidal areas. Impact and recovery depends on substrate, exposure to waves, amount and type of oil, season of oiling, and species. Grazing herbivores are especially sensitive to oil and to some of the more effective oil cleanup methods.

Intertidal filter feeders such as clams, rock scallops and mussels are also impacted by oil. Clams are impacted by oil settling into sand and gravel in their habitat. Beyond mortality, there is a long-term contamination and tainting of mussels.

Eggs and larvae of many species are planktonic and feed on phytoplankton or smaller zooplankton. Many occupy surface layers so would be susceptible to oil and potentially to seismic exploration. Beyond direct mortality, larvae are especially susceptible to slow growth that leaves them exposed to predation for a longer time. Little is known about larval feeding habits and oil impacts.

5. CARNIVORES

Most species of fish feed on euphasids or other zooplankton at some stage in their lives, some throughout their lives. Examples of the latter group are herring, sockeye, pink and chum salmon. These fish can be impacted by reduced prey abundance and possibly, transfer of oil in their prey. Most are also susceptible in the egg or larval stage, and if they are in the intertidal area. Sea otters and some sea birds prey on herbivores such as sea urchins, abalone and clams. They are susceptible to oil on the water surface and intertidal area as well as in their prey. Other carnivores, such as chinook, rockfish and halibut, that eat other carnivores generally are not exposed to oil but are locally susceptible to seismic exploration and drilling. Top carnivores, such as Orcas and seals, are susceptible to variations in food supply, tainting, exposure to oil in their habitat and to the noise of seismic exploration and drilling.

Of special concern are stocks/populations that only live in a specific local habitat. For example, many salmon populations are adapted to a specific river or area. Rockfish and prawn populations stay in their local areas. Severe local impacts could result in putting such populations at risk of extinction.

Adult fishes can directly ingest oil and oiled food, take up dissolved oil compounds through their body surfaces, or their eggs and larvae can become contaminated. The highest impacts are in shallow water, near shore. The early life stages of fish are most susceptible to oil because they often are surface and/or shallow water oriented. Also, eggs and juveniles tend to be more sensitive to oil than adults. Oil dispersants tend to increase the toxic effects on young fish and eggs. Impacts range from behavioral modification and reduced predator avoidance to direct mortality.

Oil can also affect fish, such as salmon, in tidal areas of creeks. Spawning adults, eggs and larvae in the gravel, and migrating fry or smolts are all susceptible. There is conflicting information on the scale and duration of impacts in such areas.

6. HUMAN HARVEST: The human concerns are about reduced fish production, changes in fish distribution, and tainting of catch.

Fish are not evenly distributed. Some areas are relatively barren and others may be very productive and highly populated. Some areas are especially important for spawning, nursery, feeding, or adult and juvenile migration, each with different sensitivities. Consequently, some areas and times need special protection from some oil and gas exploration, development and production activities.

Impacts on fisheries include oil-contaminated harvesting gear, temporary fishing closures of oiled areas and long-term closure of fishing in oil production and pipeline areas. Fisheries for sedentary species are more vulnerable to oil and gas impacts than those for mobile species. Harvest of intertidal species is more vulnerable than subtidal species, which in turn are more vulnerable than open ocean species. Tainting of fish flesh is a concern. Although products may be declared safe to eat, tainting might still affect the taste and/or commercial and sport consumer confidence.

OIL AND GAS DEVELOPMENT

There are three phases in oil and gas development: exploration, drilling and production. Exploration is primarily by seismic surveys using air guns. Drilling would be from some type of ocean drill rig. Production would either involve a pipeline on the ocean bottom from the well to a storage site or long-term production from the drilling platform. Each of these phases has potential impacts on fish resources and fisheries. Seismic exploration impacts vary by species, time and location. In the drilling and production phases the main concern is the potential for unplanned events and accidents that could result in oil spills or deposit of debris into the ocean.

Life Stages Highly Susceptible To Oil and Gas Development

There are periods in the life cycle of marine organisms when adverse habitat conditions result in significant decreases in survival and production. The most susceptible period is the reproductive stage - egg-larval stage in fish, nesting stage in birds, birth and early life of marine mammals. Also, organisms that are resident in inter-tidal areas are especially susceptible to habitat disruption and site-specific local impacts such as physical and chemical changes in their habitat.

“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)” cited in JWEL, 2001. In the larval life stage, growth rate is key to survival. Natural mortalities are very high in this life stage. Anything that increases mortality will impact on overall survival and ultimately on fish production. During this stage, larvae have low mobility and their location is determined by their habitat, such that they can’t avoid areas of adverse conditions. Concerns include toxic materials and factors that affect marine productivity, such as by an oil spill decreasing food organisms. Physical damage to eggs and larvae from seismic exploration is also a concern. Kostyuchenko (1971; cited in JWEL, 2001) noted that mortality of fish eggs and larvae may occur within 1 to 10 metres of an operating airgun. There has been very limited research on non-lethal long-term effects on larval fish. There are similar concerns with young birds and marine mammals.

In inter-tidal areas, an oil spill could come into direct contact with adult and juvenile fish, their food and physical habitat. This is especially a concern for marine plants and the fish (primarily invertebrates) that feed on them or on detritus. It is also a concern for marine and shore birds and land animals that might feed in inter-tidal areas.

POTENTIAL IMPACTS OF CONCERN OR UNCERTAINTY RE FISH RESOURCES[14]

O & G Phase	Impacts	Generations[15] Impacted	Area [16] Impacted	Info.[17]	Available Responses[18] Seismic
	Physical Damage				
Exploration	- mortality	1	local	some	none
	- slow growth	1	local	?	none
	- reproduction	1	local	?	none
	Stress/behavior	1	local	?	none
	Distribution	1	local	?	none
Drilling	Cuttings/mud/toxics				
	- mortality	> 1?	local	some	yes
	- slow growth	> 1?	local	?	yes
	- reproduction	> 1?	local	?	yes
	- tainting	> 1?	local	?	yes
	Noise/behavior	> 1?	local	?	none
	Attraction effect	> 1?	local	?	yes
Operations	Well/shipping leakage	> 1	local	yes	yes
	Ballast water	potential continuing problem			
	- oil	> 1	local	yes	yes
	- other species	> 1	wide	some	yes
	Pipeline	> 1	local	some	yes
Accidents	Blowouts/spills	short, medium and long-term impacts			
	- mortality	> 1?	wide	yes	maybe?
	- slow growth	> 1?	wide	some	maybe?
	- reduced reproduction	> 1?	wide	some	none
	- tainting	> 1?	wide	some	none
	Debris on sea bed	< 1?	local	yes	yes

Seismic Exploration
There are concerns about physical damage to fish by seismic exploration. It is expected that new seismic techniques would localize and minimize impacts much more than the earlier seismic exploration on the BC coast that resulted in considerable fish kills. In the past, adult fish floating on the surface were visible signs of damage. There is also concern about much less visible damage that might occur to fragile eggs, larvae,

[14] Recognizing that many impacts are situation specific and often unpredictable.

[15] Number of generations of fish impacted

[16] Size of area impacted; local is immediate area only

[17] Amount of information available on the topic

[18] Are there proven remedial actions to address\minimize the risk and impacts?

juveniles, and species that don't float to the surface. Any distributional changes resulting from seismic exploration could have a short-term affect on both the fisheries and their management.

If seismic exploration were limited to from June to October, it would coincide with the migration of juvenile salmon and the larval stage of many shellfish species, herring, and a number of other forage fish. The available research suggests that the seismic impacts are relatively local [definite mortality within 6 meters of an air gun for fish and up to 10 metres for eggs and larvae]. There is little information on non-lethal damage at greater distances from the air gun. A 3-D seismic survey would have grid lines as close as 100 meters apart (JWEL, 2001). This would mean that up to a 20% incremental mortality could be expected in surface oriented larvae in the survey area [10 meters of mortality to the left and right in every 100 meters]. There could also be damage and mortality to adult fish in close proximity to the air gun - 12% mortality of the fish in the surface layer. However, it is expected that most adult fish would avoid the area of the seismic work. Juvenile and non-migrant species could still be impacted. For example, inshore rockfish would likely not leave their home territory unless forced to. Using higher frequencies, high resolution seismic profiling could impact a broader size range of fish than regular seismic profiling.

A Norwegian study (Engas et al, 1993. cited in JWEL, 2001) found that seismic shooting affects fish distributions for 18 to 20 nautical miles (33 to 37km) on either side of the shooting area, and resulted in reduction in trawl catches by 70% in the shooting area and by 50% over the entire study area. This displacement lasted for at least 5 days. Based on published reports it is assumed that marine mammals would also avoid seismic shooting areas if given an early warning.

Table 5.1, on page 79 in the JWEL report lists maximum noise levels of Seismic Exploration Devices at 212-230 dB. However, Table 6.2, on page 112, only lists effects on fish and whales at lower than maximum air gun sound levels (e.g. 168dB elicited an alarm response from rockfish). As the decibel scale is logarithmic these differences could be significant.

If seismic shooting affects fish distributions for up to 37 km on either side, many fish within a 20km exclusion zone could be affected. Of particular concern would be the resident rockfish populations in areas such as outside of Banks and Aristazabal Islands that would be in the outer portion of the exclusion zone. Depending on the timing of the seismic work, the nursery areas on the east coast of the Queen Charlotte Islands and in many other areas, could also be special concerns.

Drilling Oil And Gas Wells

Potential impacts on fish of drilling oil and gas wells could result from disposal of drill cuttings, drill mud and toxic materials. This could affect bottom dwelling species and bottom fisheries. These impacts would likely be highest in low current areas where these materials would stay near the well. In high current areas, these wastes would tend to be spread over a considerable area, moderating their effects. There are a number of approaches for disposal of drill cuttings and discharges that reduce the risk to the natural environment. 'Produced water' has local risk of toxic components to sessile organisms and sub-lethal effects to larvae and to older invertebrates. In high current areas, mixing would moderate this effect. Based on experience in other areas, the input materials could be controlled and outputs managed to moderate impacts on organisms in the local area.

There is some concern about local impacts of drilling. All finfish have a lateral line for sensing low frequency sounds and pressure changes and ears for balance and higher frequency hearing. Consequently, it should be expected that finfish might react to drilling sounds, probably being repelled by them. Sounds are stressing for some animals and some frequencies and volumes of sound may also disrupt their normal uses of sound. [For example, Orcas use sound for echolocation and finding food, and chinook salmon react to Orca sounds to avoid capture.] The volume of sound from drilling is loud enough (up to 185 dB, Table 5.1 JWEL, 2001) to cause severe stress in the immediate area of the sound source (Table 6.2 JWEL, 2001).

Oil and gas development can also impact fisheries by drill rigs, wells and pipelines occupying fishing areas (especially key trawling areas) and by disposal of drill cuttings in bottom trawling areas.

Oil and Gas Operations

Platforms, their anchors, and pipelines require a buffer zone around them to prevent damage and potential oil leakage. The Atlantic Canada protection zones are 500 meters from the drilling rig or production platform, 50 meters from its anchors and 200 meters from submarine pipelines. Clearly, such protection zones are required. From 1974-1995, 88.9% (67,710 barrels) of spills larger than 1,000 barrels, in the US

Outer Continental Shelf were attributed to trawl or anchor damage. The size of this protection zone for a pipeline could cause a significant reduction in fishing area, depending on the location relative to centers of fishable populations and length of pipeline. In a positive sense, these protection zones could serve as no-fishing, marine protected areas.

Operational platforms in other locations provide a reef habitat that attracts fish and apparently outweighs any negative impacts of operational noise or other habitat impacts. In some locations there has been a significant stimulation of local production. Presumably, that reef effect could be enhanced by platform design and possibly by induced upwelling in the area.

There are biological concerns related to release of oil with oil tanker ballast water, storage tank displacement water, and from other sources. Introduction of exotic species in oil tanker ballast water is also of concern. Both of these concerns can be addressed by good practices.

ACCIDENTS - OIL SPILLS

Oil pollution is the biggest long-term concern related to oil and gas exploration and development. There are numerous potential oil sources that are of environmental concern, ranging from oil in displacement water in storage tanks to oil spills, leakage, blowouts, pipeline damage, and tanker and storage problems. Oil spills could affect all species resident, reproducing, or feeding in intertidal areas and salt marshes. This would include salmon, herring, abalone, sea urchins, sea cucumbers, clams, and sea and land birds and some marine mammals. Spills could also affect all plants and animals in the surface and upper layer of the ocean, including most larval fish and planktonic eggs, and marine birds and mammals.

The incidence and extent of oil spills seems to differ a lot between jurisdictions. For example, JWEL (page 95) reports that for spills related to pipeline operations in the US Outer Continental Shelf, between 1964 and 1984, there were 34,874 spills of 50 barrels or more of oil spilled per billion barrels handled. If the 34,874 spills averaged 50 barrels, the total oil spilled would have been 1,743,700 barrels or about 0.17% of production. However, the spills are "50 or more barrels", including oil spills of 50 to 999, more than 1,000, more than 10,000, and more than 150,000 barrels. If the average spill size was 525 barrels (half way between 50 and 999) it would have been 18.3 million barrels or more than 1.8% spilled. If the spills over 50 barrels averaged 1,000 barrels it would have been 34.9 million barrels, or about 3.5% spilled. In any case, this declined to 9,122 spills (0.046% to 0.9% of production) from 1985 to 2000. On page 93 of JWEL, 2001, reports another apparent source of oil spills that would double the amount spilled. For offshore platform operations, there were 34,047 spills of 50 barrels or more reported between 1964 and 1984. Between 1985 and 2000 this had dropped to 821.

In contrast, Canadian offshore spills reported in JWEL, 2001, ranged between 0.00052% and 0.00008% of oil production between 1997-8 and 2000-1. This suggests that Canada has a lot less oil spilled than the US. This may be related to misinterpretation of US numbers, more stringent Canadian requirements, shorter-term Canadian operations with newer equipment, or how Canadian spills are reported. Canadian regulations largely rely on voluntary reporting of the occurrence and size of spills (www.offshore-environment.com/drillingwastecontents.html).

LIVING MARINE RESOURCES IN QUEEN CHARLOTTE BASIN

The specific concerns related to impacts of oil and gas exploration and development are discussed for each basic group of marine plants and animals. Also, high-risk times and areas are identified, as for example, for seismic exploration or susceptibility to oil spills.

SALMON:

There are six species, many stocks and more than 5,000 populations of salmon that spawn in streams adjacent to Queen Charlotte (QC) Basin. There are many more that rear in or migrate through the Basin as juveniles and returning adults. In total, almost all BC salmon pass through the Basin, except for a small portion of some southern coho stocks and Stikine and Taku River stocks.

Chinook and coho salmon tend to rear in coastal areas for most of their marine life. They also tend to migrate north such that many coho from southern BC and chinook from southern BC, Washington and Oregon also rear in and migrate through the area.

Chum, pink, sockeye and steelhead all rear in coastal areas for a short time before moving to open ocean areas where they rear to maturity. They then migrate back to their home stream to spawn, again passing through the QC Basin.

Most spawning takes place from September to November. Most juveniles enter the Basin in the spring (May-June). Chinook and coho may be present in the area in all months of the year. Most returning adults pass through the area from June to October.

There are very important commercial, recreational and Native salmon fisheries in the QC Basin. All salmon fisheries, except commercial troll, take place inside a 20km exclusion zone so would not be directly impacted by exploration or production, except by accidental oil spills or displacement of fish by seismic exploration.

Data Sources: Spawner counts for salmon populations in the streams tributary to the QC Basin are available at www.pac.dfo-mpo.gc.ca/ops/northernfm/Areas/default.htm. Adult stock timing, migration rate and route information is available from DFO. Catch information from 1880s to the present is available. The early data is for broad areas and the more recent is by small local areas and times. Stock assessment reports are available at www-sci-pac.dfo-mpo.gc.ca/english/psarc/default.htm. There is extensive information on salmon biology in freshwater. However, in the estuary, coastal and ocean areas there is very limited information on juvenile migration routes, rates, timing, survival and growth, especially in this area.

Potential Oil and Gas Exploration and Development Concerns - Salmon

Oil & Gas	Egg	Larva	Juvenile		Adult	Fishery	Products
			Estuary	Coastal			
Seismic				✕?	?	✕?	
Noise	✕	✕	✕	✕?		?	?
Oil Spills						✕	

? = unknown; ✕ = known negative impacts; ✕? = uncertain but likely impacts

- If seismic exploration is limited to favorable weather conditions it would coincide with juvenile and adult migrations. Adult salmon are expected to be minimally affected by seismic exploration. Small juvenile salmon may not be able to move away from the shock and noise of seismic exploration.
- Much of the Outer Coastal area on the east side of the Basin is low elevation. For example, on Aristazabal Island there are 16 streams with 60 salmon populations. Streams in such areas tend to be short with much of the spawning area in or near the intertidal area. These areas could be subject to oil spills, as occurred in the Exxon Valdes spill in Alaska.
- Throughout the area, the estuaries and shallow areas where juvenile salmon rear, could also be affected by oil spills.
- Seismic exploration and drilling might cause enough noise to displace adult salmon.

HERRING

There is one herring species and five stocks that are associated with the QC Basin. The QC Islands, North Coast and Upper Central Coast (Milbanke-Queens Sounds) stocks are large. The Lower Central Coast (Area 8-10) and Johnstone Strait (Area 11-12) stocks are small and erratic. Herring spawn in March-April in sub-tidal and inter-tidal areas, usually on marine plants. They incubate for about 3 weeks before hatching into planktonic larvae. Juvenile herring feed in the coastal areas before migrating out into the Basin and the outer coast.

Hose et al (1996) reported sub-lethal lesions and morphological and cytogenic abnormalities and other sub-lethal effects on herring exposed to oil. Brown et al. (1996) suggested that affected herring were more susceptible to parasites because of their low physiological condition, but that specific causes can't be demonstrated because of poor understanding of natural recruitment. "Although much of the population level effects on herring remain speculative, the prospect of long-term sub-lethal effects on young herring cannot be discounted despite great uncertainties with the region's herring natural history." (Sloan, 1999).

The herring populations in the QC Basin support both roe and spawn-on-kelp fisheries. They also support important Native fisheries. All herring fisheries would be in the 20km exclusion zone, but could be subject to oil spills.

Data Sources: There is considerable information on individual herring populations, their biology, local spawn deposition, survival of year classes and harvests. This information is available from DFO.

Potential Oil and Gas Exploration and Development Concerns - Herring

Oil & Gas	Egg	Larva	Juvenile Coastal	Adult	Fishery	Products
Seismic		?		?		
Oil Spills	✕	✕?	✕?		✕	✕

? = unknown; ✕ = known negative impacts; ✕? = uncertain but likely impacts

- Herring larvae might be impacted by seismic exploration, in the immediate area of an air gun.
- Herring spawn in inter-tidal areas could be highly impacted by even minor oil spills. Even a thin film of oil would likely affect the oxygen exchange capabilities and other physiological processes of the eggs.
- The spawn-on-kelp fishery would also be highly susceptible to oil spills. Even small amounts of oil would taint the product. There is also a question of petroleum oil tainting of the natural oils in herring roe and flesh.

Other Forage Fish

Important forage fish, have received much less study than herring, in general, and specifically with regard to oil and gas exploration and development impacts. There has been considerable work done on the effects of oil on herring, but very little done on sand lance and oolichan.

The sand lance is a small fish that lives in shallow water where it could be subject to oil spill impacts. In the Queen Charlotte Basin, sand lance is a preferred food for rock sole, petrale sole, pacific cod, chinook, coho, lingcod, halibut, and many other fish species and some seabirds. Sand lance larvae are likely of major importance to pelagic food webs. Sand lance feed on plankton, especially small crustaceans that could also be subject to oil spill impacts. As sand lance spawn in the spring, larvae could be subject to damage by seismic exploration.

Oolichans are small, smelt-like fish with great cultural and subsistence importance to First Nations. They spawn in the estuary or low reaches of large rivers. Eggs attach to the river bottom. Larvae are washed downstream to the marine environment as free floating planktonic larvae. As they grow, they migrate out into the QC Basin where they rear for 2+ years. The juvenile oolichan are slow swimmers and somewhat fragile. The impact of seismic exploration on larvae or ocean juveniles is not known. Most life stages could be impacted by oil spills, and tainting is an important concern.

Anchovy and sardine populations are centered off California but can be important forage fish in waters off BC. They feed on plankton in the upper layers of the ocean. Presumably there is experience with oil effects on these species in California and possibly other areas.

GROUNDFISH

There are more than 70 species of groundfish in the QC Basin. This includes general groups such as rockfish, flat fish, and pelagics.

Most groundfish have planktonic larvae that usually occupy the upper 25 meters of the water column. Spawning usually takes place in the fall, winter or early spring. The larval stage is usually about 4 to 6 weeks. If seismic exploration were limited to June to October, few larvae would be subject to seismic damage.

Data Sources: For approximately 50 groundfish species, there is extensive information on fishing areas and catch by specific map square location. For example, see Fargo et al 1990, Figures 5-18, and Fargo et al

1991. There is information on spawning and nursery areas, times of spawning, and time and distribution as larvae. For example, Reef Island, off Selwyn Inlet, is an important nursery area for rock sole, the west side of Graham Island to depths of 30 m is a nursery area for at least 5 species of flatfish, and Browning Entrance is a spawning area for Pacific Cod. There is also information on seasonal and age class geographic distribution, as for example, lemon sole that occupy the inshore shallows along the east coast of Graham Island in their first year, then move into deeper water in the area in subsequent years (Ketchen, 1956, Figure 11). Also, dogfish populations move into the shallow water on the west side of Hecate Strait during the summer to feed on invertebrates, juvenile sole and other species.

This groundfish information is available in two databases at the Pacific Biological Station (PBS), one on catch and the other on biology. The catch database includes information from the early 1950s to the present. The early information is by general fishing grounds. From 1991 on the information is by individual tow and data from 1996 on is from 100% observer coverage with GPS locations. The ZN rockfish longline fishery also now has 5% observer coverage. Stock status reports for some species are available at www.pac.dfo-mpo.gc.ca/sci/psarc/SSRs/groundfish-ssrs.htm.

A model of the groundfish population assemblages in the Hecate Strait area is being constructed. This will allow exploring the dynamics of the stocks in the area and better understanding of the observed changes in populations related to habitat factors. At some future time, this model could be extended to cover Dixon Entrance, Queen Charlotte Sound and Strait and the West Coast of the Queen Charlotte Islands[19]. Such a model could help to understand the baseline situation and to explore the implications of oil and gas exploration and development in various areas of the QC Basin.

There is limited specific information on the bottom habitat in the Queen Charlotte Basin. Whenever possible, this information is being acquired opportunistically. If oil and gas exploration goes ahead, it could provide an opportunity to get detailed habitat information to go with catch and other fish information to increase the strength of the model for the area. This could be an opportunity for cooperative work.

These databases and model(s) could be available for use for oil and gas exploratory work and assessment. PBS might be contracted to do some work. There is strong staff capability and knowledge but very limited operational money to conduct fieldwork.

The most abundant and commercially important groundfish are as follows:

Flatfish are bottom fish, most of which are associated with relatively flat seabed areas. Important flatfish species in the QC Basin include:

Rock Sole[20]: there are 4 discrete populations (2 QC Sound, 2 Hecate Strait (N,S)) of this shallow water flatfish that is most abundant in northern Hecate Strait. It is harvested in a directed trawl fishery and as bycatch in the Pacific cod fishery.

English Sole[21] and Dover Sole[22]: these Hecate Strait stocks are two of the four most important flatfish stocks in BC. English Sole are mainly in northern Hecate Strait.

Halibut[23]: in the QC Basin are part of a stock that occupies a broad area along the west coast of North America.

Butter Sole[24]: stock is centered in Skidegate Inlet

[19] Note: as there is only about 12 to 15% trawlable water on the west coast of the QCI, there is limited information on the fish there.

[20] Rock Sole: Lepidsetta bileata, Lepidsetta petroborealis

[21] English sole: Parophrys vetulus (also called Lemon sole)

[22] Dover sole: Microstomus pacificus

[23] Halibut: Hippoglossus stenolepis

Turbot: is a significant Hecate Strait stock

Rockfish occupy mid-water areas with slope, shelf and near-shore species, most of which are associated with rocky, sloped bottom terrain. Some live-bearing species have internal incubation and no free larval stage. Rockfish are often very long-lived (40 plus years) and take a long time to maturity, consequently a long time to rebuild populations from any damage.

Important rockfish in the QC Basin include:

Pacific Ocean Perch[25]: stocks in Hecate Strait and Queen Charlotte Sound are the most important rockfish taken in BC waters. They live at depths of 40 to 640 meters over a cobble or rocky high relief substrate. They have internal fertilization, with the young extruded in March off Vancouver Island, later in QC Sound. Juveniles remain pelagic until their 2nd or 3rd year

Orange rockfish[26] occupy slope, shelf and inshore areas of Hecate Strait and QC Sound

Silvergray[27] and yellowtail[28] rockfish are in abundance in QC Sound

"Inshore rockfish" such as: yelloweye[29], quillback[30], copper[31], china[32], black[33], and tiger[34] rockfish, are found in rocky reef habitat as is found off of Banks and Aristazabal Islands and many other areas in the QC Basin.

There are important commercial, sport and Native fisheries for rockfish in the QC Basin.

Pelagics are mid-water species. They have swim bladders so could be subject to damage by seismic exploration. Their eggs hatch into larvae that occupy the surface waters where they could be subject to both seismic exploration and oil spills.

The pelagics include:

Pacific Cod[35]: one of the most important groundfish in the BC trawl fishery. There are major stocks in Hecate Strait and Queen Charlotte Sound. Spawning in February – March

Sablefish/Blackcod[36]: an especially high value species. There are two stocks (N, S) in BC. They spawn from January to March and are larvae from April – May. Juveniles rear in nearshore and shelf areas until age 2-5. Adults inhabit the shelf and slope water to depths of 1500 metres.

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[24] Butter sole: Isopsetta isolepsis

[25] Pacific Ocean Perch: Sebastes alutus

[26] Orange rockfish: Sebastes pinniger

[27] Sivergray rockfish: Sebastes brevispinus

[28] Yellowtail rockfish: Sebastes flavidus

[29] Yelloweye rockfish: Sebastes ruberrimus

[30] Quillback rockfish: Sebastes maliger

[31] Copper rockfish: Sebastes caurinus

[32] China rockfish: Sebastes nebulosus

[33] Black rockfish: Sebastes melanops

[34] Tiger rockfish: Sebastes nigrocinctus

[35] Pacific cod: Gadus macrocephalus

<u>Pollock[37]: are important in</u> Hecate Strait

There are valuable commercial trawl, long-line or trap fisheries for these species in the QC Basin.

Potential Oil and Gas Exploration and Development Concerns - Groundfish

Oil & Gas	Egg	Larva	Juvenile	Adult	Fishery	Products
Seismic			✕ ?	✕ ?	✕ ?	
Drill Mud			?	?	?	?
Platform				?	+ ?	
Noise	✕ ?	✕ ?	?	?	?	
Pipe. Const.			✕ ?		?	
Pipe. Ops.					✕ ?	
Oil Spills					?	

? = unknown; ✕ ? = uncertain but likely impacts; + ? = possible positive impacts;

- Noise of seismic and drilling could displace fish
- Bottom feeding species might be impacted by drill cuttings and drill mud
- Pelagic eggs and larvae, and juveniles in shallows, could be susceptible to an oil spill
- Oil could affect forage/prey species
- Some species could benefit from the reef effect of offshore platforms
- There is a general lack of knowledge of long-term impacts of oil and gas activities or accidents on the fish
- Fisheries could be displaced by changes in fish abundance and distribution, and by protection zones around platforms and pipelines

SHELLFISH / INVERTEBRATES:

There is a wide array of shellfish species in the QC Basin, including: clams, octopus, squid, abalone, shrimp, prawns, crabs, sea urchins and sea cucumbers. Most shellfish have planktonic larvae that usually occupy the upper part of the water column. The larval stage for most species is in the spring-summer, when they would be susceptible to seismic work. Many shellfish species occupy intertidal and subtidal areas where they would be highly susceptible to oil spills.

Data Sources: There is a considerable amount of information on all shellfish species caught commercially. This catch by time and area information is generally available unless limited by the Privacy Act[38]. Harvest log data is available on commercially exploited species such as shrimp, crab, prawn, octopus, geoducks, red and green sea urchins, and sea cucumbers. Information includes date, sub-area and location, depth, time, species, number and weight caught, and time fished. Some data is geo-referenced for: geoducks since late 1970; sea cucumbers since 1984; red sea urchin since mid-1980s; green sea urchin since 1987; shrimp by trawl since 1997; crab and octopus since 2000; and shrimp by traps since 2001.

[36] Sablefish: Anoplopoma fimbria

[37] Walleye Pollock or whiting: Theragra chalcogrammus

[38] For times and areas where there were 3 or fewer vessels reporting, catch would be consolidated with data from an adjacent time or area.

"Fishery Updates", available on the DFO website, report effort, landings and landed value of each fishery, and a biological synopsis, management objectives and issues, and stock assessment activities. This information helps to explain management impacts such as closures, area rotation, and protected areas.

Biological information (not related to fisheries) is available for intertidal clams, shrimp, abalone and sea cucumbers. Most survey data (published and unpublished) is in databases at PBS. Also, there is extensive staff knowledge of shellfish and experience with assessing stocks and their habitat. These and other assets would be an essential input to establishing baseline information, researching likely impacts, and doing follow-up assessments of oil and gas development. Parks Canada also has considerable resource inventory data and reports on Gwaii Haanas and other areas. LUCO has an array of resource inventory data and maps related to shellfish.

Mollusks: most are in coastal areas, are resident or don't migrate significant distances. Clams, including geoducks, occupy sand/gravel bottom areas and are filter feeders. Clams live in both the intertidal and sub-tidal areas. Abalone live on rocks in sub and inter- tidal areas, feeding on marine plants growing there. Abalone abundance is so low as to be endangered in the QC Basin. Most mollusks have pelagic eggs and larvae that may be transported by ocean currents before settling to the bottom to start their adult life.

Important mollusk species in the QC Basin include:

Native Littleneck[39] clams: occupy the mid to lower intertidal zone. They spawn from April to October and larvae are planktonic for 3 to 4 weeks.

Geoduck[40] clams: occupy sand, silt, and soft gravel areas from intertidal to 110 metres. They spawn in June-July and larvae are planktonic for 40 to 50 days. Geoducks can live to 100+ years of age.

Butter and razor clams, mussels, scallops, octopus and squid are also present in the area and are locally important.

Crustaceans, such as shrimp, prawns and crabs, live from intertidal to deep water, areas in diverse habitats throughout the QC Basin.

Important crustaceans in the QC Basin include:

Shrimp[41]: 7 species, including prawns; spawn in late fall to early winter. Females carry the eggs until they hatch. Larvae migrate diurnally moving towards the surface at night. They spend about 3 months in the water column before settling to the bottom. Habitat varies between species including rocky to mud/sand bottom to upward in the water column. They occupy coastal areas of North Coast inlets and offshore areas of the Central Coast. There are both commercial and recreational fisheries on shrimp and prawns.

Crabs: live in sandy bottom areas that are less than 50 metres depth and that are subject to moderate currents. Dungeness, red rock, red king, graceful, and golden king crabs are all harvested in the area. They are opportunistic feeders. In the fall, eggs are laid and carried externally by the female. In the spring, the eggs hatch into planktonic larvae that develop for 3 to 4 months before they settle to the bottom. They occupy areas from intertidal to 50 metres depth. There are populations of dungeness crabs[42] in Dixon Entrance (Naden Harbour, Virago Sound, McIntyre Bay), and in Hecate Strait, and the Skeena River Estuary.

Crustaceans grow by molting their shell and growing a new, larger one. During molting and the subsequent soft-shell stage, crustaceans are highly susceptible to oil pollution, as well as physical damage. Oiling has been shown to be acutely toxic to crabs (Rice et al 1977). Oiling can cause narcotization and impaired movement in crustaceans (Johnson 1977). Sub lethal effects of oil have been documented (Johnson, 1977),

[39] Native Little Neck Clam: Protothaca staminea

[40] Geoduck: Panopea abrupta

[41] Shrimp: Pandalus sp

[42] Dungeness Crab: Cancer magister

but not long-term effects. The fine sand-silt ocean areas preferred by crabs tend to trap and hold oil. Pearson et al 1980 indicates that adult Dungeness crabs can detect and avoid contaminated areas. However, crab larvae don't avoid oil and oil impacts on the larvae are not known.

Urchins and Cucumbers
Sea Urchins: 5 species in BC. Red[43], green[44] and purple are commercially harvested. Urchins live on a rocky substrate in shallow water (intertidal to 50 to 125 [140+] meters) with moderate to strong currents. They live in sub and intertidal areas, feeding on marine plants. They have planktonic eggs and larvae. Sea urchins are highly sensitive to oil.

Sea Cucumbers[45]: 30 species in BC, inter-tidal to 250 metres in a wide variety of substrate and current conditions; mainly moderate current on cobbles, boulders, crevassed bed rock. Sea cucumbers eat organic detritus. They spawn in spring to early summer with planktonic larvae for 2 to 4 months. Fishery is by divers in coastal areas and is about 3 weeks in the fall-winter.

Potential Oil and Gas Exploration and Development Concerns - Shellfish

Oil & Gas	Egg	Larva	Juvenile	Adult	Fishery	Products
Seismic	?	?	?	X ?	?	
Drill Mud			?	?	?	?
Platform				?	?	
Noise	X ?	X ?	X ?	?	?	X ?
Pipeline				X ?	?	
Oil Spills					X ?	

? = unknown; X ? = uncertain but likely impacts

- Seismic exploration could impact eggs and larvae in surface areas
- Species occupying inter-tidal areas and feeding on marine plants could be impacted by oil spills
- Seismic and drilling noise could affect distribution of mobile shellfish
- For drilling taking place in rearing and harvesting areas for shrimp, prawn, crabs, geoduck, drill mud could affect the habitat, and possibly shellfish products, unless it is carefully managed.
- Many of the invertebrate species in the area have never been assessed for their sensitivity to exposure to oil, singly or their ecosystem.
- Pipeline construction could displace some shellfish and have a short-term habitat impact. Pipelines would displace fisheries in the immediate area.
- Oil spills are the biggest concern, likely impacting some life stage of most shellfish, some long-term. Most oil spill impacts will be in intertidal areas. However, the impacts of oil on larvae in surface layers are unassessed.

OTHER SPECIES
There are a number of species of ecological, economic, and social importance that are not included in these broad categories, including: marine plants, sponges, marine mammals and marine birds.

[43] Red Sea Urchin: Strongylocentratus franciscanus

[44] Green Sea Urchin: Strongylocentrotus droebachiensis

[45] Cucumber (giant red?): parastichopus californicus

Marine Plants: There are diverse and extensive marine plants in the Basin. Those plants that are intertidal or float at or near the surface of the ocean would be affected by oil spills. Other plants would be less affected. Damage to plants would severely impact the ecosystem. Loss of marine plants removes both food and cover for many organisms, especially larvae and juvenile fish. Also, a kelp[46] is a key component in herring spawn-on-kelp.

Data Sources: LUCO has assembled a database on distribution of marine plants such as eelgrass and kelp beds. There is limited information the distribution of most other species of marine plants. Some biological information is available on some species. There is considerable traditional knowledge on local distribution of marine plants used for food or herbal remedies.

Marine sponges: There is a large "forest" of cloud sponge in the Hecate Strait area. It is a unique population. This type of glass sponge is thought to live for periods in the order of centuries. Actions are being taken to seek marine protected area status for the site. It could be highly impacted by drilling, drill cuttings, drill mud, platform anchoring, and pipeline construction.

Data Sources: The distribution and structure of these sponge forests is documented on videotape. There may also be information from trawl logbooks.

Marine mammals commonly encountered in the Basin include whales, porpoises, dolphins, seals, sea lions, otter and mink. Land mammals, such as bears, also commonly visit intertidal areas. Marine mammals show no avoidance of oiled areas and will always be at risk in a spill. Oil spills have relatively low impact on whales, dolphins, porpoises, seals, sea lions, but high impact on sea otters, and probably river otters and mink, because they lack an insulting fat layer. Seals do not avoid oil and continue to use oiled haulouts, including for birth and nursing of pups, and for summer molting. Impacts on seals include increased pup mortality and oil ingestion while nursing, and eye and brain damage. In Alaskan, after an oil spill, declines in killer whale population were observed, but observations of abundance of other whales were inconclusive. Whales and dolphins would likely be most affected by sounds of seismic exploration and drilling. Concerns have been expressed about the possibility of reduced hearing and partial deafness.

Data Sources: There are considerable amounts of information at PBS, on the abundance, distribution and biology of common marine mammals. The Vancouver Aquarium has extensive information on biology of marine mammals. LUCO maintains a database on haulout areas.

Marine Birds are an important resource in the QC Basin. Millions of birds live, breed, and migrate through the area including: albatrosses, alcids, auklets, black turnstones, cormorants, crows, eagles, fulmars, ducks, geese, great blue herons, grebes, gulls, kingfishers, loons, mergansers, murrelets, oystercatchers, phalaropes, peregrine falcons, puffins, shearwaters, storm petrels, swans, and many others. All could be adversely impacted by oil spills, leakage and low-level pollution. Birds feed at all levels of the food chain, eating vegetation, zooplankton, shellfish and fish. Many feed in intertidal areas so food supply could also be affected. Affects include mortality, reduced reproduction, growth and distribution. The worst impact is nesting failure.

Birds nest in many areas along the coast. For example:

<u>Cassin's Auklets</u> nest on Triangle Island, along the east coast of Moresby Island, particularly on Kerouard and Anthony Islands, and on the west coast of Graham Island.

<u>Rhinoceros Auklets</u> nest on Triangle Island, on Storm and Pine Islands, and in Chatham Sound, particularly on Lucy Island.

<u>Tufted Puffin</u> nest on Triangle Island.

<u>Storm Petrels</u> nest at a number of sites along the east coast of Moresby Island, particularly in Engfield Bay, on the west coast of Graham Island, on Tree Island, and on the Buckle Group.

<u>Ancient Murrelets</u> nest at a number of sites along the east coast of Moresby Island, particularly on Lyell Island, on the west coast of Graham Island, and on Byer's Island.

[46] Kelp: Macrocystis integrifolia

Marbled Murrelets nest in trees along much of the coast.

Seismic exploration would likely impact bird distribution and nesting. For example, "Cassin's Auklets are very sensitive to disturbances during the nesting period. Adults will readily desert their nests if disturbed during the incubation or brooding period." (Booth, 1999) The natural variability of bird distribution and abundance, and incomplete baseline information make it difficult to demonstrate oil impacts unless they are extreme. An accurate census of populations of even the major colonies is incomplete, especially for populations on the east coast of the Basin. Scientific information on important issues, such as offshore birds' feeding ecology, is lacking.

Data Sources: The Canadian Wildlife Service maintains databases on bird populations and distribution. LUCO also has a database on major nesting areas.

SENSITIVE AREAS AND TIMES

The many sensitivities of organisms in the QC Basin determine how big an impact oil and gas exploration and development could have on the ecosystem and on fisheries and other dependant industries there.

At some time of the year many marine and shore areas could be rated as sensitive because: they are breeding or nursery areas; fish larvae or juveniles, or young birds or mammals are present; they are important feeding areas for birds, mammals or fish; resident, non-migrating fish are present; or it is a fishing area. Breeding and nursery areas are seasonal and differ for each species. For example, rock sole spawn near Reef Island (Mouth of Selwyn Inlet) in the fall; lemon sole spawn along the northeast coast of the Charlottes; pacific cod spawn in Browning Entrance in winter, at least five species of flatfish spawn along the entire west side of Hecate Strait off Graham Island (to 30m); herring spawn in late winter on marine plants over much of the area; dungeness crabs carry their eggs through the winter to spring in Naden Harbour and McIntyre Bay; in summer, clams spawn throughout the area; and salmon spawn in fall, in streams throughout the area. Birds nesting and marine mammal birthing generally takes place in the spring or early summer in many areas around the Basin.

Many species can't avoid high-risk areas. The planktonic eggs and larvae of many species may be carried over extensive areas by currents, wind and tides. Consequently, eggs and larval fish can't avoid high-risk areas, such as those undergoing seismic survey or an oil spill. Similarly, small juvenile fish can do little to avoid such problems so are at risk to them. Nesting birds and seals and sea lions are tied to their nursery areas. All species are at least somewhat tied to their usual feeding areas. Resident fish are tied to a location either by immobility, such as marine plants, clams and mussels, or by low mobility, such as crabs, sea urchins and shrimp. Behavior also ties some resident fish, such as some rockfish species and prawns, to their local area. Such resident species are at risk to seismic exploration and to oil spills in intertidal areas.

Distribution of many fish, birds and marine mammals varies seasonally and by age. For example, in their first year lemon sole occupy shallow areas near the northeast shore of the Queen Charlotte Islands. As two year olds they move into deeper water. As three year olds they occupy even deeper areas (Ketchen, 1956). Dogfish move into shallow areas on the west side of Hecate Strait during the summer to feed. During the spring and summer juvenile salmon migrate through the area heading to ocean rearing areas. In the summer and fall adult salmon migrate through the area heading to their home streams to spawn. In response to the fish, the fisheries also change by season and between years, as illustrated in Fargo et al 1990. Migrant birds and marine mammals pass through the area in the spring and fall and many over-winter in the area. For example, shearwaters are present from about April to November. Geese, swans and ducks pass through the area in November and April. Young fur seals over-winter in the Basin.

INFORMATION NEEDS

The fisheries ecosystem in the Queen Charlotte Basin is complex and dynamic. There is considerable information on some parts of the ecosystem. However, most of the information has only recently started to be integrated into an interrelated system so that interactions and interdependencies can be explored. Much of the new data is now geo-referenced and much more area specific than earlier data. Also, as much data collection is now by onboard observers rather than fishing crew, the data are more accurate. There is now considerable information on marine fish, birds and mammals and their ecosystems, on physical and chemical environments and ocean dynamics, as well as on fisheries. Some of the new information is being collected by new sensors in digital format that can be transmitted in real time by satellite for real time analysis. There are many new technologies for sampling, analysis and presentation of information. New computer modeling for fish assemblages and their ecosystem allows better understanding of how the parts interact. Models bring together the diverse data to better understand impacts, interactions and interdependencies.

There is considerable information on things such as catch, but very little on many other things. Key weaknesses in our understanding of the biology of oil impacts remain:

- Very few of the species in BC waters would be rated as "well studied". For example, only about 10 of 60 to 70 groundfish species are being adequately assessed. Most species of marine fish, birds, plants and mammals have not been adequately assessed to provide a baseline for predicting and measuring impacts of possible oil spill impacts.
- There is an inability to differentiate natural ecosystem changes from oil pollution effects. Natural fluctuations in fish and bird recruitment are so great that even in well-studied species, oil-induced mortalities of juvenile and pre-recruit fish would have to be very large to be detectable. The same applies for many marine birds. Longer-term impacts would be even more difficult to prove.
- The greatest information shortfall is for those impacted species: that are not easily accessible, such as those not in intertidal areas; those that don't float to the surface during seismic exploration; or those that are not recovered on the shore after an oil spill.
- There is a general lack of information on impacts on species in the lower levels of the ecological pyramid that those in the upper layers of the pyramid are dependent on.
- Most impact studies have been of individual species rather than of multi-species ecosystems.
- Various agencies and groups have assembled a lot of information, but much of it is not currently interconnected. It should be brought together so that it can be interrelated, ideally in a computer model(s). This would facilitate identification of known sensitive times and areas; likely interaction impacts, important data gaps, and could facilitate agencies working together.
- There are many initiatives to structure, collect, store and analyze data and make it accessible. However, initiatives, such as the oil spill atlas for the area, are not yet complete and at least some are incompatible with others – some pieces are missing and others don't fit.
- A lot of progress could be made in baselining and understanding the living resources and possible oil and gas impacts if agencies were funded to work together to fulfill their mandates and put together the jigsaw puzzle of information.
- There is a poor understanding of long-term, chronic impacts of oil pollution. There is much more information on immediate and short-term impacts of the various oil and gas exploration, development and accidents than of medium and long-term impacts.

Information Opportunities

There are a number of possible opportunities to improve the knowledge and management of living natural resources as a byproduct of oil and gas exploration and development. Some ideas include improved:

- detailed mapping of habitat and stock information and detailed modeling of ecosystems to help identify areas for protection, as part of feasibility and planning;
- collecting detailed bottom terrain, composition and other habitat information, as part of oil and gas exploration, to input to ecosystem models;
- monitoring the ecosystem from offshore platforms - ocean monitoring [e.g. temperature, salinity, turbidity, flow direction and speed], biological monitoring [e.g. plankton, juveniles and passing fish, birds, marine mammals].

CONCLUDING COMMENTS

Offshore oil and gas exploration, development and production can't be undertaken without impacts on the environment and the organisms there. The issue is how much and what risks governments are willing to take, what contingency plans will be required, what populations will be put at risk, and how much will be invested in better understanding and addressing the risks.

At the Earth Summit in Rio, the precautionary approach or principle was agreed to be: *"Where there are threats of serious or irreversible damage, lack of full scientific certainty must not be used as a reason for postponing cost effective measures to prevent environmental degradation."* Canada has adopted the precautionary approach and made it formal government policy, including in the Oceans Act. Canada has specifically committed to a precautionary approach for conservation of fisheries resources and other living marine resources. It is not yet clear how this approach would apply to oil and gas decisions.

As oil spills, and possibly seismic exploration, could result in serious damage for many species in the QC Basin, and the damage could be irreversible for some local populations, by definition the precautionary approach should apply.

There is considerable scientific uncertainty about damage to the different life stages of many species. Part of the uncertainty is because the information currently available on marine fish, plants, birds and mammals and their habitats hasn't yet been brought together and assimilated to understand ecosystem interactions and possible short, medium and long-term impacts on most species. To adequately assess the biological implications of oil and gas exploration and development in the Queen Charlotte Basin will require bringing a number of databases together in a geo-referenced model or models of the area. For example, an expanded version of the Hecate Strait model for groundfish might be used to bring information on the various species together. This could provide the basis for assessing the impacts of various exploration and development strategies and potential accidents. It could also be used to help design and guide accident response strategies. This assimilation process would help to identify research priorities to reduce scientific uncertainty. In the longer-term, this early work would provide a basic baseline against which to assess impacts of oil and gas exploration and development, if it goes ahead.

Such a model or network of models could also be designed to receive data from real-time monitoring of the environment and ecosystem. This network of models would be a valuable tool for planning to use and manage the ocean and related land in the Basin. The model(s) could also incorporate information from the Global Ocean Observing System to provide a big picture awareness of global scale ocean changes that might be affecting conditions in BC.

As the current "lack of full scientific certainty" can't be used as a reason for postponing oil and gas exploration and development, then any strategy must include special actions to mitigate the risks of uncertainty. This should include all fail-safes and preventative actions possible, within the limitation of being cost effective. To reduce the risks, there should be serious investment in answering key outstanding research questions on the living resources in the area.

Within the spirit of the precautionary approach, "cost effective" is not just limited to the business aspects of exploration and development. Rather, it must also include the potential costs of cleaning up oil spills or trying to rebuild populations that are put at risk of extinction.

Another important aspect of the precautionary approach is assigning the burden of proof. Rather than the conservation authority or interests having to prove an adverse impact, the burden of proof should be on the proponent, whether government or industry, to prove no adverse impact. The proponent should have to answer conservation questions <u>before</u> development, not after problems can be demonstrated. Also, it is unclear who the burden of proof must be presented to – the conservation agencies, the government(s) or the public. However, if it were the government or government agencies, they would be in a conflict of interest as proponents of the development. This is currently a problem with industries such as aquaculture.

There is a tendency to be very critical of the oil and gas industry for the damage done to marine habitat and ecosystems, particularly by oil spills. The potential consequences of a major oil spill could be catastrophic for local ecosystems so require a highly risk averse approach. It is normal practice to have emergency measures plans, processes, and local equipment and crews to provide for all weather oil spill cleanup and to address other contingencies. It is also normal practice for the oil and gas industry to agree to compensation programs for any damages to the fishing industry. If requirements comparable to those for the oil and gas industry were applied to the fisheries, forest, aquaculture, transportation and tourism industries and to industrial and urban development, many of the existing adverse impacts on marine fish, birds, plants and mammals and their ecosystems would be moderated or eliminated. The impacts of these other industries tend to result in rather slower, less visible erosion of ecosystem capabilities that are difficult to prove cause and effect for, so they continue uncompensated. Can the same be expected for oil and gas?

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Appendix 16A: The Waterbird Perspective[47]

General
My comments will focus primarily on effects of spilled oil on waterbird populations. I have been involved with research on these issues since 1995, in the context of the *Exxon Valdez* oil spill in Alaska.

Review of JEWL Report
The JEWL report addresses only typical seabirds, i.e., storm petrels, cormorants, gulls, and alcids, and I consider this a major short-coming. There are many other birds in the area that would be affected by oil and gas development, and by any release of oil into the environment. Taxa of concern include loons, grebes, waterfowl (particularly sea ducks), and shorebirds. In particular, the loons, grebes, and sea ducks are especially vulnerable, given that (1) they spend much of their time floating on the ocean surface where contact with oil would occur, (2) they spend most of their annual cycle (8-9 months) on marine, nonbreeding habitats, where they could be exposed to spilled oil, (3) they occur in nearshore intertidal and shallow subtidal zones where any released oil would concentrate, and (4) the coastlines adjacent to proposed offshore development are valuable habitat for these species (particularly during nonbreeding seasons), likely supporting relatively high densities. In fact, bird populations considered to have not recovered fully from the *Exxon Valdez* spill include loons and harlequin ducks (a sea duck), as well as pigeon guillemots (a more typical seabird).

The JEWL report section addressing effects of oil in the environment on birds seems generally thorough and well researched. However, there is a sizeable body of work by Jenssen and colleagues regarding metabolic consequences of oil exposure in birds (summarized in Jenssen 1994) that was overlooked, and is quite important. Also, recent data from the *Exxon Valdez* should be included for a more comprehensive review (e.g., Esler et al. 2000a, Golet et al. 2002), especially with regard to long-term effects of catastrophic spills or effects of chronic, low-level exposure to oil (see below). In brief, the recent *Exxon Valdez* work indicated that oil was persisting in the environment much longer than previously thought. Beach surveys in Prince William Sound conducted by NOAA in summer of 2001 (12 years after the spill) detected residual oil on many beaches, in an apparently unweathered state. Further, evidence suggests that higher trophic levels, including sea ducks (Trust et al. 2000) and sea otters, continue to be exposed to *Exxon Valdez* oil. Finally, the data indicate that for some bird populations, the oil spill had long-term, population demographic consequences through direct and indirect pathways (Esler et al. 2000a, Golet et al. 2002). These data are contrary to the conventional paradigm that oil spill effects are limited to acute, short term consequences for bird populations.

Important Considerations
As development of offshore oil and gas is considered, and potential effects on the environment generally and wildlife in particular are debated, it is important to recognize that oil pollution can occur under different scenarios with different effects. As described above, short-term, acute effects of catastrophic oil spills are widely recognized as having effects on individuals and sometimes populations. However, long-term effects from spills and effects from chronic, low-level oil pollution are just beginning to be recognized as significant threats to bird populations. In fact, for some sensitive species, these less obvious effects are likely more damaging from a population-level perspective than one-time mortality in the wake of a major spill. This has important implications for considering acceptable levels of risk of chronic, small oil releases associated with offshore development.

Also, it is important to recognize that bird species will vary in their population responses to acute or chronic oil contamination, based on variation in life history and natural history attributes. For example, bald eagle populations apparently recovered within a few years following the *Exxon Valdez* oil spill (Bowman et al. 1995, 1997), whereas, harlequin duck populations remained unrecovered and still suffered continued injury at least 9 years after the spill. Interestingly, the ecologically similar Barrow's goldeneye

[47] Submission to Dr. Patricia Gallaugher, Member – BC Offshore Hydrocarbon Development Scientific Review Panel, prepared by Dan Esler Centre for Wildlife Ecology Simon Fraser University January 2002.

showed fewer demographic responses to the spill (Esler et al. 2000b). These data indicate that subtle differences in habitat use, energetics, or life history strategy can have important implications for vulnerability to effects of oil, as well as recovery time following oil contamination. In general, species that occur in nearshore (vs. pelagic) habitats, eat invertebrates (rather than fish), have little metabolic flexibility, and have life histories oriented towards long reproductive life spans and relatively low annual productivity are those that are most susceptible to population-level effects.

Similarly, effects of oil contamination can be expressed as (1) direct, continued effects (such as toxicity and associated mortality or effects on reproduction), (2) indirect, continued effects (such as changes to trophic webs), and (3) no continued direct or indirect effects, but full recovery constrained by the time necessary for a depressed population to return to pre-perturbation levels. Number 3 is rarely considered, but may be very important for long-lived species with relatively low intrinsic population growth rates. Hence, these effects should be considered when conducting risk assessment evaluations.

Finally, the criteria used for evaluating the health (and recovery status following a spill event) of populations and communities have been variable and controversial (Wiens et al. 2001, Irons et al. 2001). Occurrence of at least some individuals of most species has been considered appropriate (Wiens et al. 1996), while others have defined differences in demography and population trajectory as evidence of continued injury and lack of recovery (e.g., Esler et al. 2000a). This inevitably becomes a value judgement, and should be discussed in the context of risk assessment prior to development.

Recommendations for Research and Monitoring

If one lesson rings loud and clear from the *Exxon Valdez* experience, it is that pre-perturbation baseline data are absolutely critical for understanding what resources are at risk from development, as well as evaluating the population and community level consequences following development. In the context of considering offshore oil and gas development in BC, it seems that a critical part of the risk assessment procedure should include quantification of wildlife populations in the area. Further, this quantification should not be in the form of one-time distribution and abundance surveys, but also should include baseline information on demographic processes, population structure, and current contaminant/biomarker levels. Specifically, I recommend:

- monitoring of seabird colonies for abundance and indices to productivity (e.g., chick growth); some of these data exist, although recent data are spotty for many sites.
- monitoring of waterbird distribution and abundance, particularly during winter. Coastal BC is a globally important nonbreeding area for sea ducks, loons, grebes, and other birds. However, distribution and abundance have been poorly quantified, with replication over time and space practically nonexistent. Survey methodologies for similar environments and taxa have been developed (e.g., in southeast Alaska); these could be applied easily to the BC coast.
- directed studies to quantify demographic processes. The importance of this can not be overstated. Studies of survival, movements, and productivity allow not only measures of population change, but also lend insight into the underlying mechanisms leading to that change. These are difficult, and often overlooked, but offer the strongest data for understanding how environmental change affects bird populations.
- discern population structure; in other words, determine the size and spatial extent of the population segments that may be affected by environmental change. Again, this is a critical, but often overlooked, metric when considering both potential impacts of proposed development and effects of environmental change on populations. For example, a population of widely moving, interacting individuals will be structured at a fairly large scale, and local changes will likely have little effect on distinct population units. Conversely, species that show strong site fidelity and limited interaction will be structured at a much smaller scale, with demographically independent population units occurring within local areas that in turn are vulnerable to small scale environmental change or development. Population structure often is inferred from genetic information and movement data from marked individuals.
- finally, evaluation of contemporary contaminant and biomarker levels (such as cytochrome P4501A for oil exposure; Trust et al. 2000), provides benchmarks for assessing contamination related to oil and gas development.

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Appendix 16B. Considerations for Seabirds in Western Canada, British Columbia, in regards to Offshore Gas and Oil Development[48]

Seabirds are among the most obvious members of the marine ecosystem, and they are commonly used as indicators for the health and condition of this huge habitat (Furness and Monaghan 1987) which is so difficult to survey and to monitor as a whole. Sea- and waterbirds are also among the most dominant victims when oil spills (Burger 1997) and other catastrophes occur. Therefore, these animals have attracted much of the attention in the public and scientific community (see also Wiens et al. 1984). The following sections of this short report, requested by the Centre for Coastal Studies, will review major points on what is currently known on seabirds (Campbell et al. 1990), seabird baseline data (Morgan et al 1991) and population estimates (Rodway 1991) for the waters of Western Canada, British Columbia. In addition, knowledge gaps will be identified and suggestions will be made how the current picture on Western Canadian seabirds in their unique and diverse habitat can be completed. This should help to assure that a solid, updated and internationally comparable situation could be reached safeguarding this unique ecosystem and their members.

Review of Seabird Population Estimates

Populations are rarely confined to bureaucratic and administrative units; this situation is particularly true for seabirds which migrate across borders and which move within the entire Pacific (e.g. Morgan et al. 1991); an ecosystem that underlies large-scale regime shifts (e.g. Thomson 1981). Besides major methodological topics on ‘counting birds’ (e.g. Bibby and Burgess 1992, Kepler and Scott 1981), the described situation on populations in administrative units fully needs to be reflected in the use of the term ‘Population Estimates’. In concert with knowledge on distribution (Vermeer et al. 1988, Emms and Morgan 1994) and wildlife communities (e.g. Wiens et al. 1978, Huettmann and Diamond 2001), accurate population estimates are crucial for a sound management and assessment of human and natural effects (Wiens et al. 1984, Burger 1993). Approximately 16 species of seabirds are breeding on the coast of British Columbia (Campbell et al. 1990, Rodway 1991). It is not the objective of this brief review to address population estimates, population trends and further details for individual species. Overall, the Canadian Wildlife Service estimates that more than 5.5 million colonial birds nest at over 500 known locations. According to Morgan et al. (1990) (for reasons mentioned further in the text, the weak but only source for seasonal abundance estimates), the most abundant species are likely Sooty/Short-tailed Shearwaters, Gulls (California, Glaucous-winged, Herring/Thayer's), Black-legged Kittiwake, Common Murre, Auklets (Cassin's and Rhinoceros), Murrelets (Ancient and Marbled) and Storm-Petrels (Leach's and Fork-tailed). Species like Albatross (Black-footed, Laysan and Short-tailed), Thick-billed Murre, Horned Puffin, Brandt's Cormorant, other shearwaters (Flesh-footed, Buller's, Black-vented and Pink-footed) and Petrels can likely be considered to be rare in Western Canada. Nevertheless, these abundance estimates always need to be seen and interpreted in the global context. Except for Marbled Murrelets (Yen et al. in prep), almost all seabirds in B.C. breed on colonies, which are generally located on islands or directly at the coast (Campbell et al. 1990, Rodway 1991). However, most seabirds do not breed earlier than a minimum age of 2 years, frequently even at an older age, and colonies are only used by these seabirds for less than 3 months of the year. In most cases, less than 50% of the entire seabird population does actually breed. Therefore large numbers, if not even the majority, of seabirds in Western Canada are not accounted for when focusing alone on breeding seabird numbers on colonies (see Morgan et al. 1993 for pelagic (appr. >10km away from land) and winter survey and knowledge gaps).

Seabirds are an integral part of the ecosystem; they depend directly (e.g. Vermeer 1981, Vermeer et al 1985) or indirectly (e.g. as the key prey item for fish species) on plankton, which therefore presents the driving force for the overall marine food-chain seabirds depend on. However, except for prey information collected with relative ease from breeding seabirds at the colonies, no data exist on what seabirds prey on; this is particularly true for seabirds offshore and in winter. The waters of Western Canada are biologically

[48] Submission to Dr. Patricia Gallaugher, Member – BC Offshore Hydrocarbon Development Scientific Review Panel, prepared by Falk Huettmann, Biology Department – Simon Fraser University January 2002.

among the richest in the Pacific, and thus attract vast and still unknown numbers of seabirds from the entire Pacific and beyond. Of interest to seabirds are normally 'breeding cliffs' and biologically rich areas, e.g. some unique shelf-, shelf-edge and coastal zones. Relevant areas include the rich waters off Vancouver Island, the calm fjords benefit from glacial run-off and strong tidal mixing, the undisturbed coastlines (e.g. compare also Vermeer et al 1998a), the 'hot vents' (sources of hot water on the sea floor, Thomson 1981), the Queen Charlotte Island Sound, and the Queen Charlotte Island region. The latter area, and specifically the eastern and southern sections of Queen Charlotte Island, is well known for its year round abundance of Pacific long-distance migrants (e.g. Sooty/Short-tailed Shearwaters, and to a lesser extent Black-legged Kittiwake) and of breeding birds (e.g. Storm-Petrels, Herring/Thayer's Gulls, Ancient Murrelet, Rhinoceros Auklet) (Morgan et al. 1990). Many more important and unique areas exist, e.g. around Triangle Island, but are usually not known due to lack of investigations and surveys. Currently, the seafloor of B.C. is not fully GIS-mapped even (see Huettmann and Lock 1987 for linking seabird occurrence with seafloor depth for management purposes). Nevertheless, these waters in B.C. are of global importance for many seabirds (A. Gaston pers. com.). Short-tailed Albatross and several shearwater and storm-petrel species present additional and major conservation topics (Melvin and Parrish 2001) which have not really been studied and monitored in Western Canada; topics like these can only be guessed from situations elsewhere, where these or similar species occur (Montevecchi et al. 1999, Wiese et al. 2001).

Data Situation for Seabirds and Seabird Studies in Western Canada

Basic information and data on seabirds in Western Canada are available and do exist, e.g. to be found in the grey literature or in scientific publications (Rodway 1991), but many gaps and uncertainties remain. For seabird colony data and population trends, most of the information is either old (normally around 1989; contact D. Bertram for latest Cassin's Auklet and breeding seabird numbers on Triangle Island), or carry no or huge confidence intervals; they cannot always be used reliably for management and science since they are not fully accepted by experts (sensu Buckland et al. 1993, Reed and Blaustein 1997, Thomas and Martin 1996, Thomas and Juanes 1996, Thomas 1997). The best seabird colony information is given by Rodway (1991), with additional and more detailed information presented by Drent and Guiguet (1961), Campbell (1976), Campbell and Garrioch (1979), Rodway et al. (1988, 1990, 1992), Rodway and Lemon, (1990, 1991a b), Rodway et al. (1994). As outlined previously, seabirds counted on colonies do not present the entire population in the overall region. There is no survey in B.C. known to the author that combines seabird colony estimates with the remaining non-breeding and offshore population. Also missing are seabird density surveys (e.g. Tasker et al. 1984, Ford and Qualis 1984, Bibby and Burgess 1992, but see Vermeer et al. 1983), in order to obtain valid pelagic abundances (Vermeer et al .1987). Much of the colony information deserves major updates, valid statistical methodology and more intense and BC-wide survey methods (reference?). The proportion of surveyed animals on which inference on population trends is drawn tends to be very small, or ignores the overall Pacific population context (e.g. Vermeer and Devito 1989, Vermeer et al. 1989b). For the pelagic ocean, seabird surveys do exist and were partially published (Morgan et al. 1991); however, the survey intensity across time and space is low. Most of the spatial and temporal survey effort was driven by convenience and regions with potential threats from oil drilling (Morgan et al 1991) and does not capture the realities of the ecosystem (extend and changes). Therefore, it does not capture the entire picture and biological reality for seabirds in sound statistical terms as required for management. It can be concluded that many data gaps exist, and that many zoological surprises and new findings on seabirds in B.C. will still be made in the future. It can also be concluded that statistically sensitive findings such as trends or Canadian population estimates - major informations required for sound and transparent management and conservation - are not updated, nor available for many of the seabird resources. Thus, safeguarding seabirds in B.C. is currently not really possible, e.g. population targets do not exist or are unclear and highly debatable. In case of oilspills and other catastrophes, disagreements about their effects and impacts are likely to arise among experts and the public. This situation is not desirable and deserves clarification towards objective and accepted approaches and results.

Seabirds and Flaring on Offshore Platforms

For over millions of years oceans were not, or only marginally, affected by humans and therefore this habitat needs to be seen as a true 'wilderness' (Huettmann 2000a). Offshore oil drilling, oil platform structures and flaring (burning off gas) present a habitat change, a disturbance, never experienced by most members of the pelagic ecosystem and 'not supposed' to occur in a truly natural situation. Flaring activities can occur on such a magnitude that they can be monitored with satellite imagery (Muirhead and Cracknell

1984 in Wiese et al. 2001). Offshore oil drilling platforms can present an additional habitat ('artificial reef') in the feature-less ocean, which results into more abundant marine wildlife (Montevecchi et al. 1999 for a review; Wolfson et al. 1979, Shinn 1974; see Tasker et al. 1986 for seabirds). In addition, it is well known that light on the ocean during the night normally attracts plankton, fish and (sea-) birds (Wiese et al. 2001 for an overview; see also Keitt 2001, Keitt et al. 2001) alike; thus, marine wildlife is artificially high around these structures. Birds are believed to be attracted to and killed at (lightened) structures (Avery et al. 1980 for overview; Terres 1956, Weir 1976, Verheijen 1981), and be burnt directly by the flare (Sage 1979, Bourne 1979, Hope-Jones 1980, Crawford 1981, Wallis 1981, Wood 1999). Mitigation measures are hardly known, but see Reed et al. (1985). None of these effects are described and studied in Western Canada. In addition, passerine and shorebird migration and offshore flyways are not fully known for Western Canada, but should be considered for studies on the impact of flaring. Triangle Island (and certainly Farallon Islands off San Francisco) suggest already that a strong bird migration over the ocean exist, which is likely affected by flaring activities.

Research Suggestions to Safeguard Seabirds in Western Canada

Currently, pelagic seabird research and information on seabirds in Western Canada is not undertaken on Canadian and international standards. Considering the outlined shortcomings such as apparent lack of awareness on seabird issues in management circles, the entire lack of solid and statistically sound baseline ('pre-spill') data for the unique seabird resource in Western Canada, major efforts are required to bring Western Canada up-to-date to a decent and international standard. In the following, some topics are mentioned that should be considered for a sound science-based management:

- Holding a Workshop with international experts to review the state of seabirds in Western Canada and set priorities and budgets for scientific and holistic seabird research, its organization and management.
- It is crucial to define leadership for seabird resources, including their habitats and the entire marine ecosystem. Are DFO (Department of Fisheries and Oceans), CWS and the Provincial Governments (many Ministries) really looking effectively after seabirds? A definition and jurisdictional confirmation is needed towards a science-based multidisciplinary approach. DFO has never seriously supported and/or taken the lead on seabird issues ever in Canada, but is highly suggested to get involved (see also and Melvin and Parrish 2001).
- Long-term data collections and inventories are needed to provide sound baseline data (e.g. considering regime shifts), and are to be continued and intensified.
- Major effort to secure funds and cooperative project funding with partners beyond the governmental scope.

Additional research suggestions are given in the Annex

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ANNEX Additional Research suggestions

- All interactions that seabirds have with their environment need to be understood in order to fully appreciate how oil development and flaring affects seabirds in Western Canada; therefore, seabird-fisheries interactions need to be known and studied in depth (e.g. Wahl and Heinemann 1979). This includes seabird movement studies and the effects of fishery discard and by-catch (Melvin and Parrish 2001).
- Regular Beached Bird Surveys (e.g. Camphuysen 1989) are to be carried out at the entire B.C. coast, e.g. following strict survey formats used in Pacific Northwest (Hass and Parrish 2001) or Newfoundland (Wiese and Ryan 1999).
- Compilation of all existing survey data in B.C., e.g. carried out earlier by contractors and agencies, into one database (e.g. Huettmann and Lock 1997) to obtain the best possible picture of historic seabird distributions and abundance. In addition, 'fragmentation' of seabird data in B.C. and Canada is to be avoided in the future by assuring collected data are centralized and available to the general public in a digital format.
- High intense seabird surveys with valid sampling schemes, e.g Density Surveys (Tasker et al. 1984) and DISTANCE sampling (Buckland et al. 1993) and as used elsewhere and for other sea animals (sea mammals), are to be carried out. A valid survey design with strategic surveys, based on a group of trained and constantly evaluated observers, is necessary in order to obtain high quality survey data (Kepler and Scott 1981). Opportunistic surveys (vessels of opportunity such as B.C. ferries, cruise ships and research vessels), and systematic surveys (specifically repeated routes on DFO vessels, Coast Guard and others) could easily be used in a cost-effective manner.
- In order to fill information and knowledge gaps for un-surveyed areas and for evaluation purposes, predictive GIS Modelling should be used (e.g. Huettmann 2000, Huettmann and Diamond 2001b, Yen et al. in prep). Results from this approach can be published as a (Canadian) Atlas, need ground-truthing and should then be used for future research, e.g. developing global change and fisheries scenarios.
- Full inventories for seabirds, their prey and habitats, e.g. plankton, herring, sandlance and others (for Marbled Murrelets it would require coastal Old-Forest Inventories). These seabird abundances, habitats and prey data should be analysed with meaningful statistics, e.g. towards transparent ecosystem classifications and Marine Protected Area delineations.

- A specific and science-based Western Canada GIS Data Center is to be set up for marine (pelagic and coastal) ecosystem data. DFO, Industry, NGO, governments (Federal, Provincial) and Conservation Data Centers (CDCs), could be contributing members.
- Additionally, advanced research projects are to be carried out (applied questions and curiosity driven), e.g. behavioural effects of seabirds from additional food sources (flaring, fisheries), satellite-based seabird habitat studies, studying lesser known seabird species such as Storm-Petrels.

Appendix 17: Federal Government Responsibilities

Oceans Act
Canada's Oceans Act came into force January 31, 1997. Canada's Oceans Jurisdiction is described in the table below.

CANADA'S MARITIME ZONES
Overview:
The Act declares a contiguous zone and an exclusive economic zone.
Canada now has four maritime zones.

Under the Oceans Act:

ZONE

DEFINITION

RIGHTS & RESPONSIBILITIES

Territorial Sea (TS)

The TS extends 12 nautical miles from the baseline

Full rights and responsibilities may be exercised within this zone

Contiguous Zone (CZ)

The CZ extends 12 nautical miles from the outer edge of the TS

Canada's rights and responsibilities in this zone allow us to prevent and take action with respect to the commission of offences on Canadian territory relating to customs, sanitary, fiscal and immigration laws

Exclusive Economic Zone (EEZ)

The EEZ extends 200 nautical miles from Canada's baseline

Canada may exercise rights and responsibilities with respect to the exploration and exploitation of living and non-living resources of waters, subsoil and seabed in the EEZ; right to conduct marine scientific research; right to take measures to protect the marine environment

Continental Shelf (CS)

The CS includes the seabed and subsoil from the outer edge of the Territorial Sea to the outer edge of the Continental Margin, or to 200 nautical miles, whichever is greater

Canada may exercise rights and responsibilities with respect to the exploration and exploitation of mineral, and other non-living resources and of living resources (sedentary species only)

Appendix 18: Risk Assessment and Management[49]

1 Rational Decision-making and Risk Analysis

1.1 Decision-making

Since the present report focuses on risk aspects, a few comments on the methodology of rational decision-making would assist in the present report. Decisions under uncertainty consist of a choice of decision (for instance whether to drill a well), followed by chance events (for example a blowout), shown in Figure 1. The probabilities of the chance events, together with an assessment of the consequences, assist in the choice of an optimal decision.

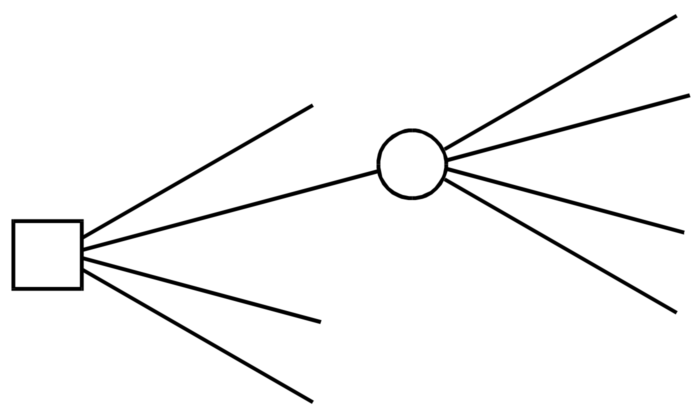


Figure 1 Decisions are indicated by rectangles and chance events by circles

1.2 Risk Analysis

Risk analysis is a branch of decision theory but the events under consideration are undesirable ones. As in decision analysis, risk analysis requires that consideration be given to consequences of actions as well as their probabilities. Taking a scale of consequences from 1 (most desirable) to 0 (least desirable), Figure 2 shows the region of interest in risk analysis. It is convenient to use probabilities calculated on an annual basis, so that, for example, the annual risk to an individual, or of an oil spill, is assessed. It is generally useful to express the probability on a logarithmic scale (lower part of Figure 2); usually the range under consideration is from about 10^{-2} to 10^{-7}, giving a range on the log scale of 2 to 7.

The consequence scale deals with events that might include single, several or many deaths and injuries, small or large oil spills, minor or major damage to the environment, or combinations of these. Aversion to risk and the consideration of utility can be built into the analysis. Decisions can be designed to reduce risk, for example, the decision not to permit the discharge of drilling muds and cuttings.

[49] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Ian Jordaan and Associates – January 2002.

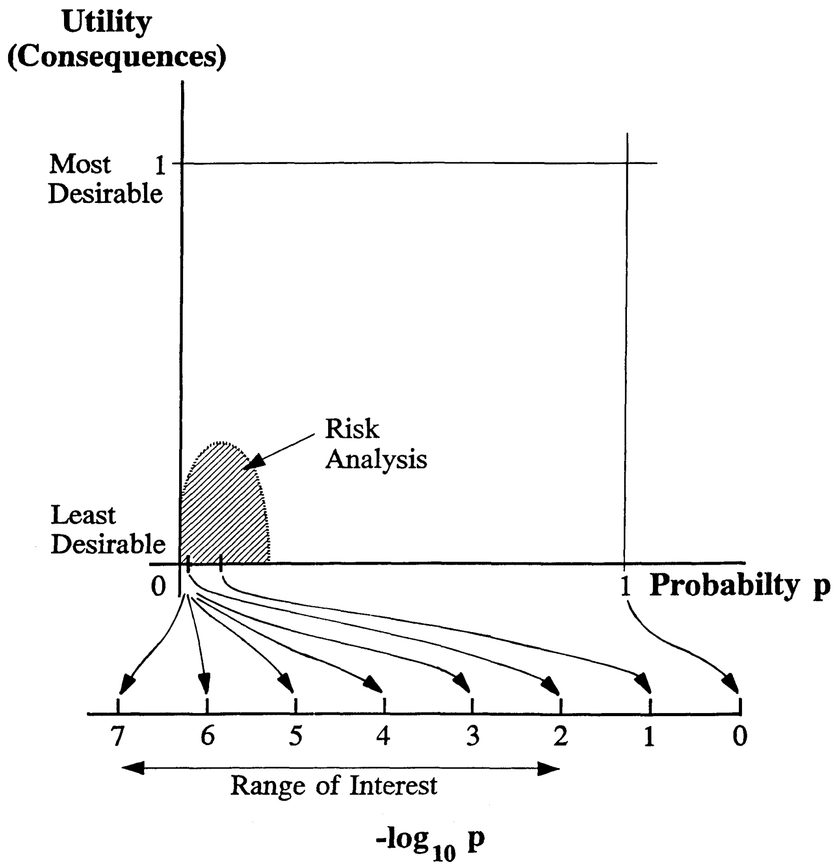


Figure 2 Area of interest in risk analysis

2 Discussion of Reports

The 1986 report by an environmental assessment panel recommended that certain exploratory activities proceed subject to a large number of conditions and precautionary requirements. Nevertheless the moratorium continued. The 1996 report by the Canadian Ocean Frontiers Research Foundation reviewed technical and other progress since 1986. Many of the concerns regarding technical and administrative issues raised in 1986 have been addressed by developments and experience since then. Two further technical concerns were raised, the first regarding lack of understanding of biological resources at risk and the second the lack of risk evaluation and determination of acceptable standards. The JWEL report has been the main focus of the present effort. The report highlights the points of concern related to development in this area such as the affected marine life, climatic conditions, and hydrological conditions. It should be noted that environmental impacts in the area will also be a function of factors such as the regulatory environment regarding effluent discharges and type of drilling fluid to be used. In this area with a sensitive ecosystem these factors may have a significant effect.

The report, while identifying the relevant risks, does not constitute a quantitative risk analysis (QRA) which would permit the relative magnitude and importance of the various risks to be assessed. It is important for those involved in decision-making to understand the risks. For example, in dealing with oil spills, the exposure basis could be structured so as to assist in understanding. One might wish to determine the probability of a spill per unit of time (year for example) per activity (e.g. per drill rig). The unit of spills per “billion barrels handled” does not convey the risk for activities in the exploration phase. Further, the QRA approach would assist in dealing with the link between probability and severity.

The distinction between acute and chronic environmental effects is also of importance when assessing environmental risks. Oil spills are most likely to cause an acute environmental impact, that is the impact affects the ecosystem rapidly, such as oiling of marine mammals resulting in an inability to thermoregulate. These types of impacts can be prevented and mitigated with proper procedures. At the Aquatic Toxicology Workshop 2000 held in St. John’s, NF it was shown that in the case of produced water discharges from platforms the long term or chronic impacts on the surrounding ecosystem are not well known and may be significant. This type of chronic impact would be especially important for low energy waters (i.e. shallow water, slow currents, etc…) where dispersion of the produced water plume is inadequate. The long term impact the platform and discharges may have on flora and fauna populations and marine animal migration, breeding and other activities are also difficult to quantify without a more detailed risk assessment.

For the purposes of the present activity, the JWEL report may be sufficient for decision-making. At the same time, it is recommended that a quantitative risk assessment focussing on probabilities and consequences be carried out either immediately or at a later stage in the process, before exploration proceeds.

2.1.1 Engineering Design

The area under consideration is prone to storms with high winds and associated waves and storm-driven currents. It is also an area of high seismicity. These facts have been discussed in the report. Current engineering practice can deal with these aspects which have been the subject of considerable research in recent decades.

One omission in the report is reference to the Canadian Standards Association (CSA) Code for Offshore Structures, currently being updated. The standard was formulated so as to achieve target safety levels of (1 - 10^{-5}) per annum. The loads specified for earthquakes, fore example, are set at annual probability exceedance of 10^{-4} per annum. (Standard S.471). The Canadian environment was very much the focus of this reliability-based standard. Some background information is given at the end of this appendix.

2.1.2 Quantitative Risk Assessment

As noted above, quantitative risk assessment would be most useful as a means to rationalize and set levels of safety for offshore activities. Certainly the methodology assists in identifying the most important potential impacts. The most significant of these is probably that of oil spills. This will be discussed as an example, in terms of probabilities and consequences. This is intended as an initial overview in conformity with the mandate to provide a review, and not a detailed analysis. We initially focus “attributes”, and for this we consider volume of spill, which is of great importance.

2.1.2.1 Oil Spills—Probabilities

To gauge risk, one aspect is the probability associated with the events, linked to the attributes. A first point that should be made that the record has been improving, both in industry generally and in the offshore industry specifically. Data to illustrate this trend from the US Coast Guard is shown in Figure 3. This is for all spills in U.S. waters. Figure 4 shows the annual rates for various sizes of crude oil spill and for all substances including gas and light oils; data are from WOAD, (1996). (WOAD is DnV’s Worldwide Offshore Accident Databank) for mobile offshore units. The rates for larger spills are declining over time. For the years 1980-1995, and for volumes in the range 118-1177 m^3, the rate is slightly higher that 10^{-4} per annum. The mobile offshore rigs are mostly used for drilling and the rate “per unit-year” provides a ready gauge of risk for a particular well-defined activity. It should be noted that probabilities are linked to the attribute under consideration, that is volume of spill in the present case.

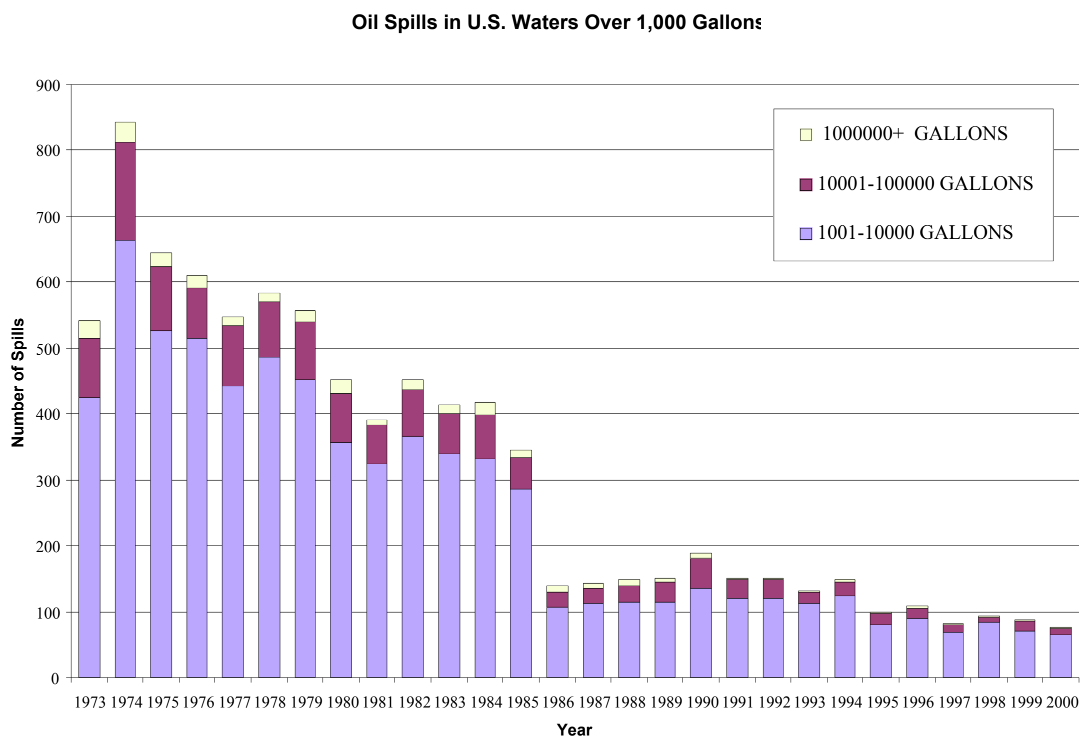
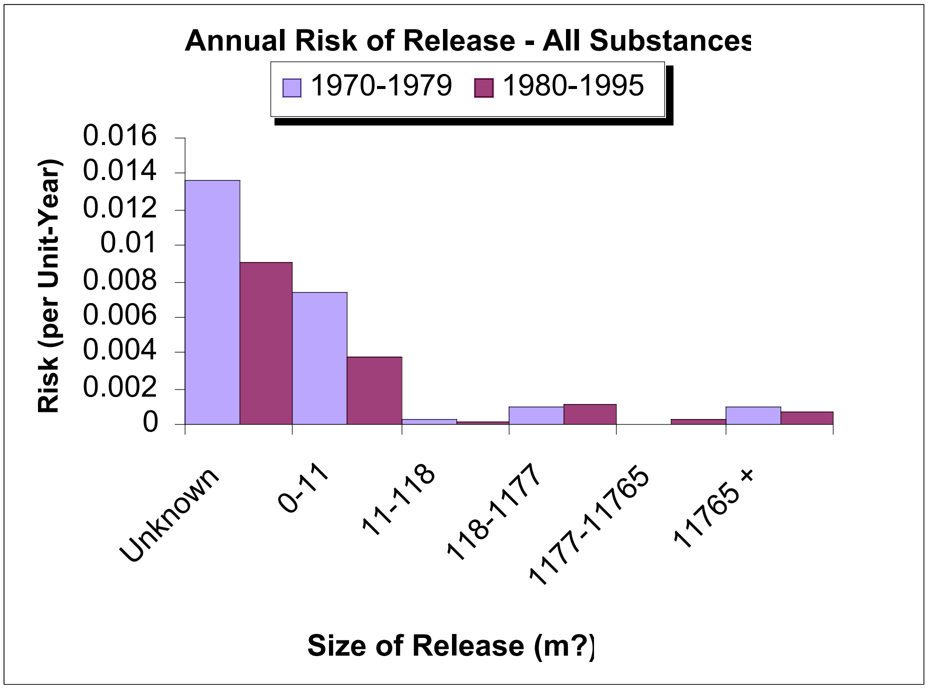


Figure 3 Trend showing declining rate for larger oil spills (U.S. Coast Guard data)



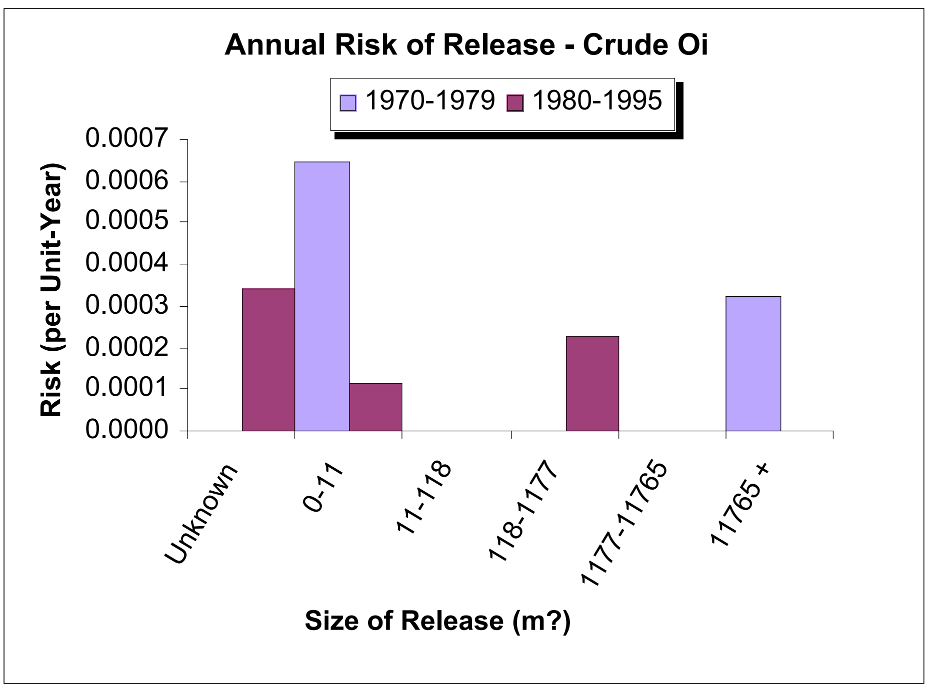


Figure 4 Crude oil and substance release statistics; mobile offshore units (WOAD)

2.1.2.2 Oil Spills-Consequences

In risk analysis, consequences need to be analyzed, in addition to the probability. We considered above the volume of the spill as the main attribute. Consequences should be linked to the attributes under consideration. The effect of oil spills in the marine environment is a function also of other parameters, including water conditions (temperature, salinity, currents, for example), climatic conditions, and type of oil spill (heavy versus light oil). For instance, a heavy oil spill where the temperature of both the water and air are low might result in the rapid formation of emulsions and tar balls which would have a much different impact than a lighter oil spill in a warmer environment (where evaporation may be more prevalent). Water and climatic conditions will affect the mechanism of oil transport (chemical, photochemical, and biochemical reactions) and physical processes (such as emulsification) and dispersion.

There are also chronic effects associated with oil spills, for instance an oil spill in a warm environment may be cleaned up rapidly through self purification processes. This process may result in a change of the ecosystem from one with very diverse flora and fauna to one of less diversity due to the conditions that favour a particular type of microorganism or plant life.

3 Conclusions

Offshore hydrocarbon exploration and development cannot be undertaken without impacts on the environment. The subject area is a sensitive one and care is needed in any development. The objective should be to maintain risks at an acceptable level and to mitigate them. There is sufficient evidence in the JWEL report to suggest that all of the risks have been identified. Safety has been improving in the industry and it seems reasonable to reconsider the moratorium. Techniques and methodology are available for dealing with risks. Decisions with regard to lifting the moratorium and proceeding with development can be taken on this basis. Before actual exploration and other activities take place, there is a need for quantitative risk analysis. This will provide an appropriate vehicle for decision-making in which the various stakeholders can assess the situation.

Risk analysis will also assist in defining the regulatory environment. Decisions can be made regarding (for example) procedures for mitigation of oil spills, effluent discharges and type of drilling fluid to be used. It is probable that the practice and regulatory environment in Canada is such that risks would be on the low end of the scale.

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Review of Risk Levels

With regard to risk to human life, the level "basic risk" R_0 is defined as the risk that is impossible to avoid in living in society. This is often taken as a proportion (about one-third) of the risks due to all accidents. Taking the value from Statistics Canada, it is found that

$$R_0 \approx 1.4 \times 10^{-4}$$

per annum. The level of 10^{-4} is often given as a desired maximum risk, for example Table 1, from Wells (1996). Figure 5 shows that, large accidents aside (from which lessons have been learned), the level of 10^{-4} is achievable in the offshore industry. Generally risk will be considered with regard to all causes and also with regard to a single cause (see for example Table 1)

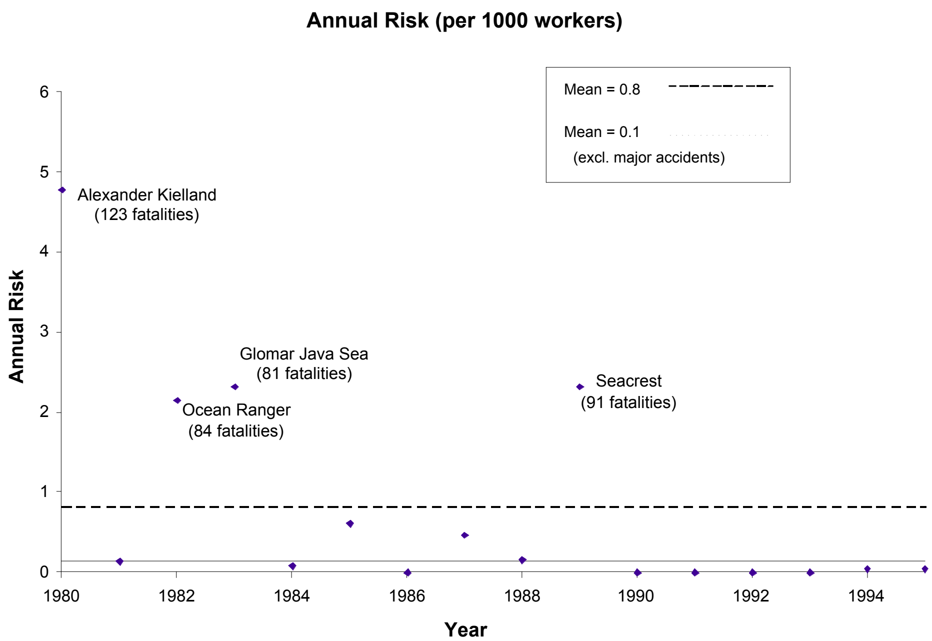

Figure 5 Risk for personnel on mobile offshore units (based on WOAD)

Table 1 Risk Values Recommended by Wells (1996)

Target values of maximum risk not to be exceeded	
Employee individual risk	
• all process causes	10^{-4} per year
• specific process causes	10^{-5} per year
Public individual risk	
• all process causes	10^{-5} per year
• specific process causes	10^{-6} per year
Risk of major accidents (that is societal risk)	
• near miss from all process causes	10^{-4} per year
• accident from all process causes	10^{-5} per year
• catastrophic accident from all causes	10^{-6} per year
• accident from specific process causes	10^{-6} per year
• catastrophic accident from specific process causes	10^{-7} per year

Other scenarios other than those involving loss of life are of interest in the present case. In this regard, CSA (1992) treats “large loss of life” and “major damage to the environment as being equivalent.

Canadian Standards Association (1992) (currently being updated)

A brief summary of the safety aspects will be given pertaining to the Canadian Standards Association CAN/CSA-S471-92, General Requirements, Design Criteria, the Environment, and Loads, part of the Code for the Design, Construction, and Installation of Fixed Offshore Structures. This Standard sets the safety objectives for the code as a whole. An important aspect is the question of safety classes. These are defined in clause 4.5.2. The Standard defines two safety classes for the verification of the safety of the structure or any of its structural elements:

(a) Safety Class 1 - failure would result in great risk to life or a high potential for environmental damage, for the loading condition under consideration;

(b) Safety Class 2 - failure would result in small risk to life and a low potential for environmental damage, for the loading condition under consideration.

The main target safety level used in the calibration of the CSA code corresponded to a failure probability of 10^{-5} per annum. Target safety levels for safety class 2 and for serviceability (impaired function) were given as 10^{-3} and 10^{-1} per annum, respectively. Table 2 is reproduced here, from Appendix A of the Standard S471.

Table 2 Annual Exceedance Probabilities for Specified Loads

	Safety Class 1		*Safety Class 2*	
	Annual exceedance probability, p_E	Load factor	Annual exceedance probability, p_E	Load factor
Specified loads, E_f, based on frequent environmental processes	10^{-2}	1.35	10^{-2}	0.9
Specified loads, E_r based on rare environmental events	10^{-4} to 10^{-3}	1.0	10^{-2}	1.0
Specified accidental loads, A	10^{-4} to 10^{-3}	1.0	N/A	N/A

Appendix 19: Drilling History Offshore the Westcoast of British Columbia[50]

Summary

Between 11 June 1967 and 5 May 1969 Shell Canada drilled 14 exploration wells off the BC coast line in water depths ranging from 70 feet to 556 feet. Seven of the wells were located off the Tofino coast line, and the remainder were drilled in the marine portion of the Queen Charlotte basin. Most of this latter effort was expended in the Hecate strait.

The greatest range of water depths encountered were in the Queen Charlottes area, where two of the wells were in water so shallow that the Sedco rig was positioned on the sea floor. Elsewhere it was anchored.

For this study use was made of the time breakdown provided in all of the Drilling history reports filed with the BC government. There are several reasons why the data should be treated with caution.

- Drilling Tour sheets are not available: these would contain a much more detailed time allocation for the 12 hourly shifts, and form the basis for contract settlement between the operator (Shell) and the drilling contractor (Sedco). The Tour sheets are probably on file with the National Energy Board.
- Allocating rig time for purposes of contract settlement do not necessarily provide an unbiased view of the impact of the environment on drilling operations. Operational and contractual flexibility may have masked the impact of weather of sea state
- The preparation of the well history reports was not done to a rigorous standard, and the detailed of reporting varies from well to well.
- The history reports lack any detailed information on weather and sea states
- The history reports lack any information about sea floor conditions.

The well files in the possession of the National Energy Board are likely to contain far more information relevant to the interpretation of the information presented in the History reports. All that this paper can do is provide a first cut at describing what happened thirty three years ago.

Overview

Table I provides an overview of the wells and the time during which operations were carried out. This includes two winters' drilling seasons (67/68 and 68/69) when the weather could be expected to have a significant impact on offshore activities. This is confirmed by the two wells to which weather delays were attributed: -Zeus I-65, spudded on Feb 5 1968 (10 days Waiting on weather -"WOW") and Harlequin D-86, spudded on 17 September of the same year (17 days).

Overall operations became shorter in duration as the drilling program advanced. The first three wells too on average 63 days to drill and the last three took 22 days to drill. Not all wells were the same depth, but other factors appear to overshadow this aspect.

Rig moves

Table II provides rig move information. In the well records rig move time was always allocated to the next well. No rig move time was noted for the very first well (Prometheus). Rigmove time includes anchor handling and the move itself.

The accompanying figure suggests that weather impacts played no significant role. The two fastest rig moves took place during the winter months. However the two identified sprinters (Tyee N-39 and to Coho I-74) had two unique features: the rig moves were long (618 and 712 km respectively) and in both cases the rig was not anchored, but set on the sea bed. Anchor handling is time consuming portion of the overall

[50] Submission to the Scientific Review Panel, BC Offshore Hydrocarbon Development prepared by Bou van Oort, Senior Advisor, BC Ministry of Mines and Energy – January 2002.

rig move statistic and therefore would have a disproportionate impact on short rig moves. Without more detailed information it is difficult to derive weather related conclusions from this information.

Water Depth

Water depths are presented on Table III. For the Tyee N-39 well and the Coho I 74 well the rig was positioned on the floor of the Ocean as previously mentioned. The subsea BOP stack was nevertheless run, but the rotary table elevation above mean sea level was higher for these two wells than for the other wells. The stable platform thus obtained might permit operations under more severe conditions than for a floating location. Nine wells including these two apparently had no weather related delays.

No information is available in the well records on the quality of the sea floor at the various locations.

Mud Weight information

Table IV presents mud weight and drill penetration data. It will be noted that for the first few wells Shell used high mud weights of almost 18 lbs/gallon. The reason is not explained: was this deliberate or accidental? No mention is made of the planned mudweight in the drilling applications on record. A high mud weight has the apparent benefit of preventing unwanted influx of formation fluids, and therefore apparently reducing the risk of a blowout.

High mud weights do detract from formation evaluation because of the tendency to flush the bore hole wall with mud filtrate well ahead of the bit, and exposes the well to other drilling problems, such as stuck pipe and loss of circulation. This last item may increase the risk of a blow out by reducing the hydrostatic head for shallower, gas bearing formations. It is therefore perhaps no coincidence that the Pluto well encountered a shallow gas kick at about 1300 feet. The kick was controlled by closing the BOPs and it took only a 9.2 lb/gallon mud top control the flow. Such shallow gas pockets tend to be low volume events.

An added concern is the need to lace the mud with diesel oil to overcome differential pipe sticking problems (stuck pipe). This detracts from unambiguous chromatograph record interpretation of the returning mudflow.

A lower mudweight moreover tends to speed up bit penetration rate. Table IV demonstrates that Shell was alive to these concerns, and after the first Zeus well, changed its mud practices. The last few wells were drilled with 9-9.5 Lb/gallon mud. The table moreover indicates that drilling progress was materially improved by this change of policy; the penetration rate rose from about 200 ft per day to almost 500 feet per day. The Zeus I-65 well and the Murrelet L-15 well both achieved the same depth. A glance at the time statistics of Table I shows that overall operating days, and therefore including time lost for releasing stuck pipe, conditioning the mud, and coping with fishing jobs also was sharply reduced. This would suggest that the later wells were drilled in a less risky manner than the earlier wells.

Overall there is no indication that Shell encountered any serious problems specifically attributable to the unique environment they were operating in.

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Bou van Oort

November 2, 2001

TABLE I: Rig time allocation overview

Well Name	Operating period From	to	TD ft SSL	Total Time days	Time breakdown Rig move days	Operating days	WOW days	Miscel days
Prometheus H-68	11-Jun-67	09-Aug-67	-7549	60	0	56	0	1
Pluto I-87	09-Aug-67	12-Oct-67	-12117	64	3	58	1	1
Zeus I-65	12-Oct-67	05-Feb-68	-9868	103	8	74	10	8
Zeus D-14	05-Feb-68	31-Mar-68	-7872	41	8	25	1	6
Tyee N-39	31-Mar-68	19-May-68	-11254	49	7	40	0	0
Sockeye B-10	19-May-68	22-Jul-68	-15540	64	2	60	0	1
Sockeye E-66	22-Jul-68	12-Aug-68	-9028	20	1	18	0	1
Auklet G-41	12-Aug-68	29-Aug-68	-7663	17	3	9	0	2
Osprey D-36	29-Aug-68	17-Sep-68	-8190	19	3	16	0	0
Harlequin D-86	17-Sep-68	01-Nov-68	-10521	45	9	18	17	0
Apollo J-14	01-Nov-68	22-Jan-69	-10040	81	49	32	0	0
Cygnet J-100	22-Jan-69	20-Feb-69	-7958	29	4	22	0	0
Coho I-74	20-Feb-69	05-Apr-69	-9005	32	8	24	0	0
Murrelet L-15	05-Apr-69	05-May-69	-9467	30	8	20	1	0

Time allocation per well

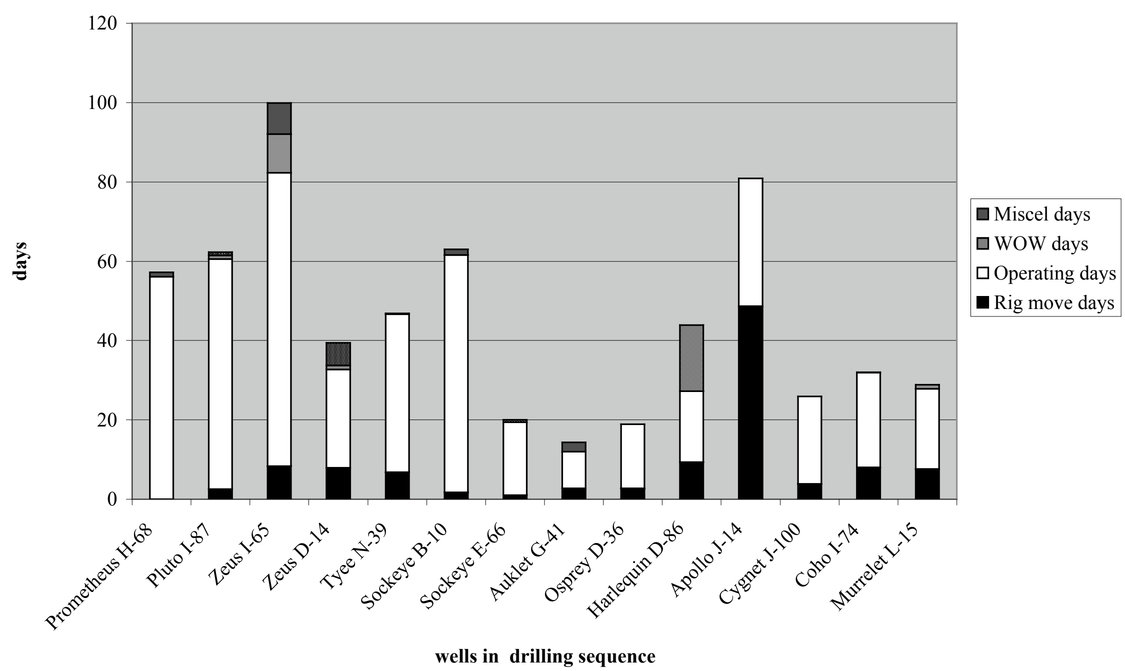


TABLE II: Rig moves

Well Sequence	Rig -move km	days	to Well	Spud date	Rig move time Km/day
1	0	0.0	Prometheus H-68	11-Jun-67	0
2	41.5	2.5	Pluto I-87	11-Aug-67	16.6
3	15.5	8.3	Zeus I-65	04-Nov-67	1.9
4	7.5	7.9	Zeus D-14	24-Feb-68	1.0
5	618.0	6.8	Tyee N-39	07-Apr-68	90.7
6	60.0	1.7	Sockeye B-10	21-May-68	35.5
7	10.0	1.0	Sockeye E-66	23-Jul-68	9.8
8	51.5	2.7	Auklet G-41	14-Aug-68	18.9
9	120.0	2.8	Osprey D-36	01-Sep-68	43.0
10	57.5	9.3	Harlequin D-86	22-Sep-68	6.2
11	350.0	48.7	Apollo J-14	23-Nov-68	7.2
12	152.0	3.9	Cygnet J-100	26-Jan-69	39.5
13	712.0	8.0	Coho I-74	12-Mar-69	89.0
14	135.0	7.6	Murrelet L-15	13-Apr-69	17.8

Rig move Efficiency versus date

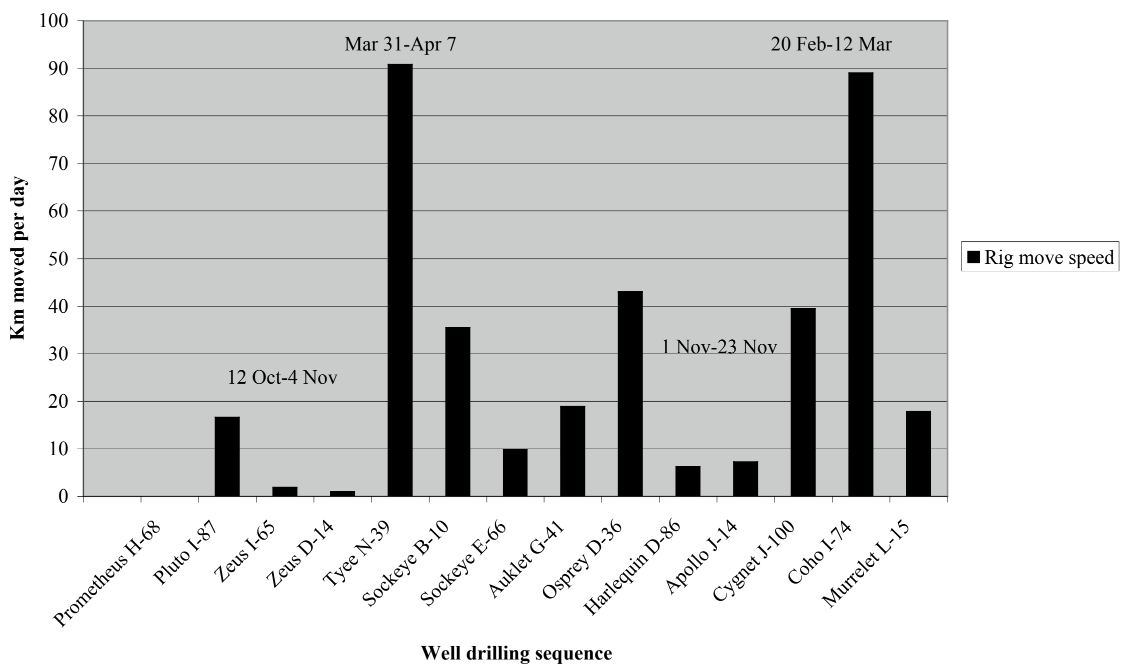


Table III : Water depths

Well Name	Area	Water Depth ft SSL
Prometheus H-68	Tofino	-181
Pluto I-87	Tofino	-197
Zeus I-65	Tofino	-323
Zeus D-14	Tofino	-459
Tyee N-39	Queen Charlottes	-90
Sockeye B-10	Queen Charlottes	-102
Sockeye E-66	Queen Charlottes	-183
Auklet G-41	Queen Charlottes	-556
Osprey D-36	Queen Charlottes	-192
Harlequin D-86	Queen Charlottes	-459
Apollo J-14	Tofino	-464
Cygnet J-100	Tofino	-485
Coho I-74	Queen Charlottes	-70
Murrelet L-15	Tofino	-364

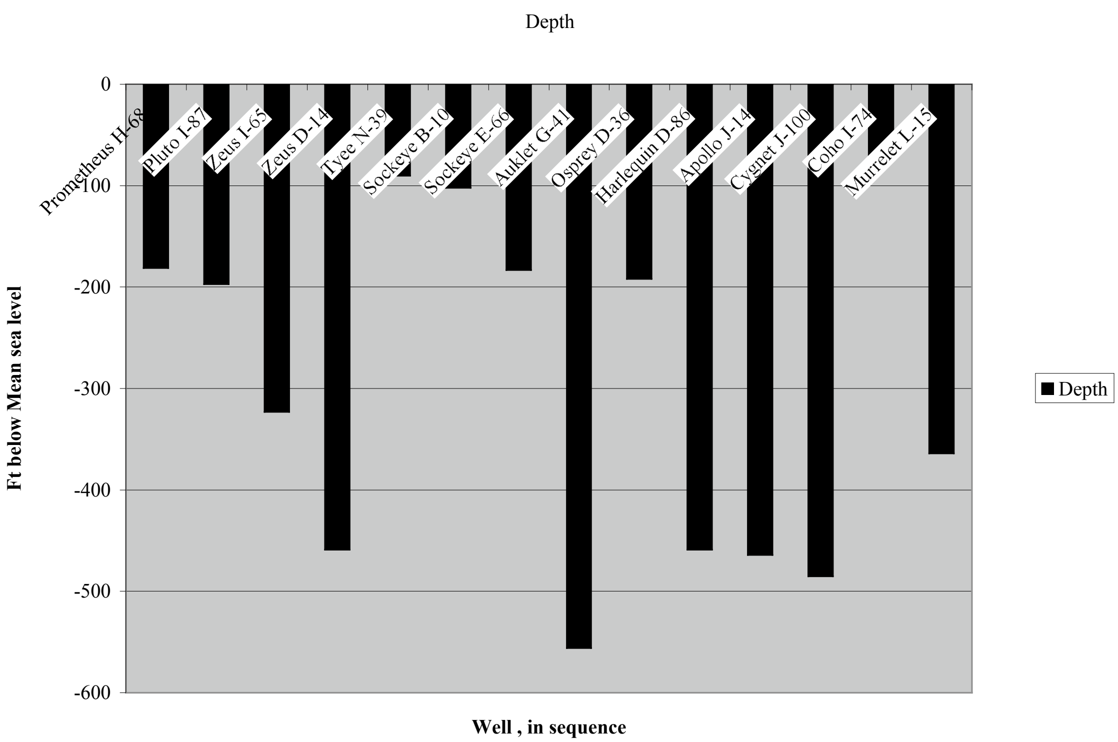
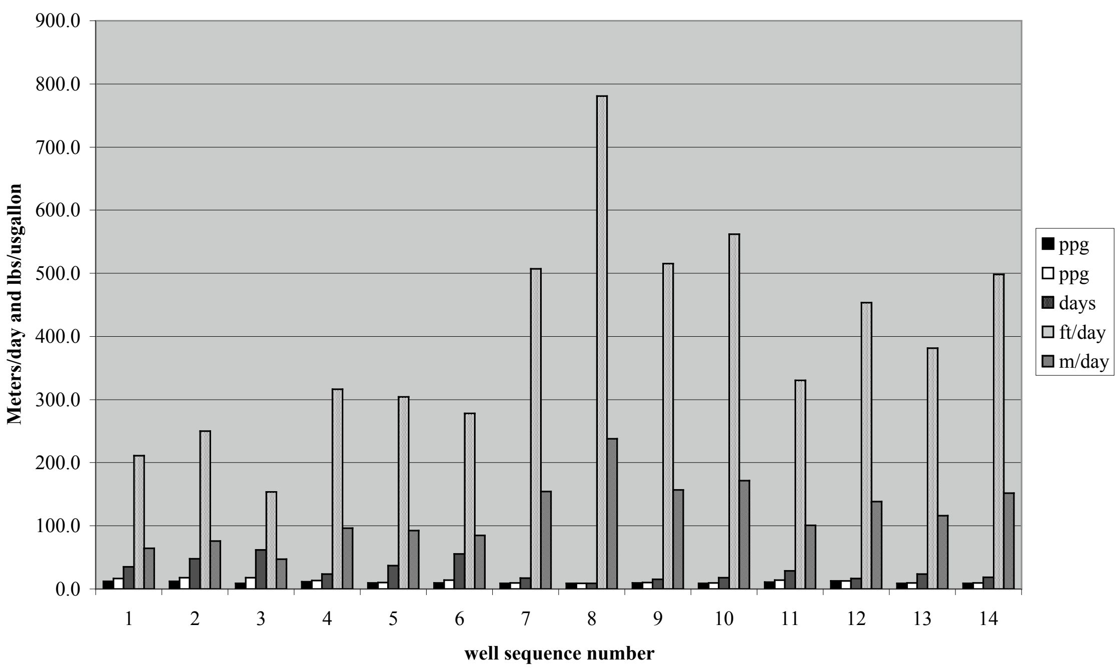


TABLE IV: Effect of mud weight on drilling

Well Name	mud weight from ppg	to ppg	Drilling efficiency days	ft/day
Prometheus H-68	12.3	16.6	34.9	211
Pluto I-87	12.3	17.9	47.7	250
Zeus I-65	9.2	17.7	62.0	154
Zeus D-14	11.5	13.5	23.4	317
Tyee N-39	9.6	10.0	36.7	304
Sockeye B-10	9.4	14.3	55.5	278
Sockeye E-66	9.1	9.4	17.5	507
Auklet G-41	9.0	9.0	9.1	780
Osprey D-36	9.8	10.4	15.5	515
Harlequin D-86	8.9	9.6	17.9	562
Apollo J-14	11.1	14.1	29.0	331
Cygnet J-100	13.0	13.0	16.5	454
Coho I-74	9.0	9.5	23.4	381
Murrelet L-15	8.9	9.5	18.3	498

Drilling speed versus mudweight



Appendix 20: Lowell Statement on Science and the Precautionary Principle[51]

Growing awareness of the potentially vast scale of human impacts on planetary health has led to a recognition of the need to change the ways in which environmental protection decisions are made, and the ways that scientific knowledge informs those decisions. As scientists and other professionals committed to improving global health, we therefore call for the recognition of the precautionary principle as a key component of environmental and health policy decision-making, particularly when complex and uncertain threats must be addressed.

We reaffirm the 1998 Wingspread Statement on the Precautionary Principle and believe that effective implementation of this principle requires the following elements:

- Upholding the basic right of each individual (and future generations) to a healthy, life-sustaining environment as called for in the United Nations Declaration on Human Rights;
- Action on early warnings, when there is credible evidence that harm is occurring or likely to occur, even if the exact nature and magnitude of the harm are not fully understood;
- Identification, evaluation and implementation of the safest feasible approaches to meeting social needs;
- Placing responsibility on originators of potentially dangerous activities to thoroughly study and minimize risks, and to evaluate and choose the safest alternatives to meet a particular need, with independent review; and
- Application of transparent and inclusive decision-making processes that increase the participation of all stakeholders and communities, particularly those potentially affected by a policy choice.

We believe that effective application of the precautionary principle requires interdisciplinary scientific research, as well as explicitness about the uncertainties involved in this research and its findings. Precautionary decision-making is consistent with "sound science" because of the large areas of uncertainty and even ignorance that persist in our understanding of complex biological systems, in the interconnectedness of organisms, and in the potential for interactive and cumulative impacts of multiple hazards. Because of these uncertainties, science will sometimes be incapable of providing clear and certain answers to important questions about potential environmental hazards. In these instances, policy decisions must be made on the basis of sound judgment, open discussion, and other public values, in addition to whatever scientific information is available. We believe that waiting for incontrovertible scientific evidence of harm before preventive action is taken can increase the risk of costly mistakes that can cause serious and irreversible harm not only to ecosystem and human health and well-being, but also to the economy.

Some of the ways that scientific information is currently applied in formulating policy can work against the ability to take precautionary action, for example by misrepresenting limitations in the state of scientific knowledge. Decision-makers frequently look for high levels of proof of causal links between a technology and a risk before acting, so that their decisions will be protected from accusations of being arbitrary. But often, high levels of proof cannot be achieved, and are not likely to be forthcoming in the foreseeable future. A more complete and open presentation from scientists on the current limitations in understanding of environmental risks will encourage the acceptance on the part of government decision-makers and the public of the idea that precautionary action is a prudent and effective strategy when potential risks are large and uncertainties are large as well.

It is not only the communication between scientists and policy makers, however, which needs improvement. We believe that there are ways in which the current methods of scientific inquiry may also

[51] December 17, 2001. Statement from the International Summit on Science and the Precautionary Principle Hosted by the Lowell Center for Sustainable Production, University of Massachusetts, Lowell, Massachusetts, 20-22 September 2002

retard precautionary action. For example, research frequently focuses on narrow, quantifiable aspects of problems, thus inadvertently excluding from consideration potential interactions among different components of the complex biologic systems of which humans are a part. The compartmentalization of scientific knowledge further impedes the ability of science to detect and investigate early warnings and develop options for preventing harm when far-reaching health and environmental risks are involved. Unfortunately, limitations in scientific tools and in the ability to quantify causal relationships are often misinterpreted by government decision-makers, scientists, and proponents of hazardous activities as evidence of safety. However, not knowing whether an action is harmful is not the same thing as knowing that it is safe.

We contend that effective implementation of the precautionary principle demands improved scientific methods, and a new interface between science and policy that stresses the continuous updating of knowledge as well as improved communication of risk, certainty, and uncertainty. With these objectives in mind, we call for a re-evaluation of scientific research agendas, funding priorities, science education, and science policy. The ultimate goals of this effort would include:

- A more effective linkage between research on hazards and expanded research on primary prevention, safer technological options, and restoration;
- Increased use of interdisciplinary approaches to science and policy, including better integration of qualitative and quantitative data;
- Innovative research methods for analyzing the cumulative and interactive effects of various hazards to which ecosystems and people are exposed; for examining impacts on populations and systems; and for analyzing the impacts of hazards on vulnerable sub-populations and disproportionately affected communities. Systems for continuous monitoring and surveillance to avoid unintended consequences of actions, and to identify early warnings of risks; and
- More comprehensive techniques for analyzing and communicating potential hazards and uncertainties (what is known, not known, and can be known).

We understand that human activities cannot be risk-free. However, we contend that society has not realized the full potential of science and policy to prevent damage to ecosystems and health while ensuring progress towards a healthier and economically sustainable future. The goal of precaution is to prevent harm, not to prevent progress. We believe that applying precautionary policies can foster innovation in better materials, safer products, and alternative production processes.

We urge governments to adopt the precautionary principle in environmental and health decision-making under uncertainty when there are potential risks, as well as to take timely preventive and restorative actions in cases where damage has been demonstrated. The elements of decision-making processes incorporating the precautionary principle, as outlined above, represent necessary aspects of sound, rational processes for preventing negative impacts of human activities on human and ecosystem health. This approach shares the core values and preventive traditions of medicine and public health.

Annex A: Signatories (not included here)

Annex B: Wingspread Statement on the Precautionary Principle, January 1998

The release and use of toxic substances, the exploitation of resources, and physical alterations of the environment have had substantial unintended consequences affecting human health and the environment. Some of these concerns are high rates of learning deficiencies, asthma, cancer, birth defects and species extinctions; along with global climate change, stratospheric ozone depletion and worldwide contamination with toxic substances and nuclear materials.

We believe existing environmental regulations and other decisions, particularly those based on risk assessment, have failed to protect adequately human health and the environment, the larger system of which humans are but a part.

We believe there is compelling evidence that damage to humans and the worldwide environment is of such magnitude and seriousness that new principles for conducting human activities are necessary.

While we realize that human activities may involve hazards, people must proceed more carefully than has been the case in recent history. Corporations, government entities, organizations, communities, scientists and other individuals must adopt a precautionary approach to all human endeavors.

Therefore, it is necessary to implement the Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

In this context the proponent of an activity, rather than the public, should bear the burden of proof.

The process of applying the Precautionary Principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.