B.C. Offshore Hydrocarbon Development: Issues and Prospects

A Background Report Prepared by the Maritime Awards Society of Canada

The Maritime Awards Society of Canada

The Ocean Centre of Excellence British Columbia Institute of Technology

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Douglas M. Johnston and Erin N. Hildebrand, Editors

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Preface

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 which are designed to raise awareness and enhance understanding of public policy issues related to the ocean in general and to Canada's coastal waters.

In launching its public awareness program in 1995, MASC organized a public forum on oceans issues, using the title "Four Problems in Search of Solutions", intending to pursue a number of topics more intensively in a series of future public meetings, initially to be organized every two years. In 1996, the focus in a well-attended public forum at the University of Victoria was on fisheries management; the report of that meeting was widely circulated and is available on the MASC website under the title "Politics, Management and Conflict in the Canadian Fisheries." For its 1998 meeting, MASC planned a workshop at Dunsmuir Lodge to explore the issues surrounding the federal and provincial moratoria on exploration for hydrocarbon (oil and gas) resources lying under the seabed in offshore areas, particularly in and around the Queen Charlotte Basin adjacent to the coast of British Columbia, anticipating that the question of lifting the moratorium would shortly become a more active issue on the public policy agenda. In the event, that workshop had to be cancelled, but MASC returned to the subject for its year 2000 program. In the meantime, the question had indeed become more actively pursued, and a public meeting and invitational "think tank" organized at Simon Fraser University in May, 2000 resulted in the development of extensive background materials and some media attention. Building from that background, MASC undertook to organise, in October 2000, an informal meeting of senior B.C. and federal government officials with academic and other specialists to review the knowledge available on the possible risks and benefits associated with offshore hydrocarbon development in light of current technologies. The workshop was also designed to canvass processes for public discussion that might be put in train as a preliminary to any government or corporate decisions surrounding the moratorium. That meeting concluded with a session examining possibilities for a series of further public meetings over the 2000/2001 year.

From that discussion we concluded that the Maritime Awards Society of Canada could make a contribution to public awareness of the issues associated with the moratoria by preparing and making available on its website the present summary paper. It is hoped the paper might be useful as background to public meetings on the subject in Northern British Columbia, on Vancouver Island, or in Vancouver and Victoria. This report was drafted by Douglas Johnston, Professor Emeritus of Law at the University of Victoria, with supporting materials and bibliography prepared by Erin Hildebrand, Ph.D. candidate at the University of Victoria. MASC thanks are extended both for their contribution to the workshop and this background paper, and thanks are also extended to the sponsors of the informal advisory review meeting: the British Columbia Ministry of Energy and Mines; the British Columbia Ministry of Environment, Lands and Parks;

BC Fisheries; and the Northern Development Commission. Also, the invaluable assistance of the Ocean Centre of Excellence at the British Columbia Institute of Technology, which acted as our partner organisation in this activity, is also gratefully acknowledged. Responsibility for the opinions expressed in this report rests with the authors. The report does not necessarily reflect the opinions of the Maritime Awards Society or any of the sponsoring or partner organisations. Nor does it necessarily represent the contributions of the individuals associated with the workshop, who participated in a personal capacity.

A. R. Dobell, President
Maritime Awards Society of Canada

B.C. Offshore Hydrocarbon Development: Issues and Prospects

The History of Offshore Hydrocarbon Exploration in B.C.

World interest in offshore hydrocarbon recovery began to acquire an operational significance in the late 1930's, when platform technology entered its infancy through pioneering installations in the shallow waters of Lake Maracaibo in Venezuela, and subsequently in the Gulf of Mexico. Since then offshore hydrocarbon production has become a familiar activity in numerous regions around the world, often contributing very significantly to adjacent economies.

In B.C. an interest in offshore exploration can be traced back almost 50 years, but throughout most of this period exploration has been suspended through moratoria, first provincial and then also federal. Initially these bans were based on legal uncertainties whether the offshore areas in question came under provincial or federal jurisdiction. Between 1966 and 1968, after expiry of the first provincial moratorium, 14 offshore wells were drilled in response to speculative geological estimates of a large reserve off the coast of northern British Columbia. However, the continuing jurisdictional dispute between the federal and B.C. governments resulted in the re-imposition of a provincial moratorium Shortly thereafter in 1972, the federal government reacted to environmental concerns over the potential impact of tanker traffic by imposing its own moratorium on such traffic between the Queen Charlottes and the B.C. mainland. Subsequently, the federal ban was extended to offshore drilling. Since then the permits granted for exploration in these waters four decades ago have been "frozen".

In the early 1980's, the recovery of oil prices on the world market and federal incentives to open up offshore operations under the National Energy Program induced the industry to re-assess the prospect of offshore production off the coast of British Columbia. On behalf of the permit-holders, Chevron took the lead in proposing the lifting of the moratoria. In accordance with both federal and provincial policy and legislation, federal-provincial hearings were conducted between 1984 and 1986, involving extensive consultations with the public in general, and in particular with First Nations and other affected coastal communities.

As a result of these consultations, the Panel recommended the lifting of the moratoria subject to 92 conditions. Most of these conditions can be brought under five broad headings: (i) approval to proceed with further exploration should be contingent upon a research programme designed to enhance the scientific community's understanding of the local marine environment that would be most directly affected by such operations and of its capacity to withstand the impact of oil pollution; (ii) approval to proceed should depend upon guarantees that the best available clean-up and other technologies would be deployed; (iii) offshore operations should be brought under a strong and effective regulatory regime designed specifically to meet West coast requirements; (iv) staff capabilities within the government service and in all sectors of industry should be brought up to the highest levels before the commencement of production; and (v) other forms of preparation, including the negotiation of joint contingency plans and the

development of integrated oil spill response mechanisms, should also precede the commencement of operations.

More specifically, the Panel called for: continuing consultations with the First Nations and with the general public; rigorous environmental assessments; imposition of both spatial and seasonal constraints on seismic studies; and the establishment of an initial closure policy based on "no drilling" zones within 20 km from the shoreline. Research requirements identified by the Panel included such topics as ocean currents, weather forecasting, seabed site surveys, bird population counts, baseline coastal inventories, sensitivity mapping, and the lethal and sub-lethal impacts of crude oil on salmonids and other species. The need to develop a fully professionalised inspectorate was also emphasised.

With a view to the lifting of the moratoria, the B.C. and federal governments in 1987 began to negotiate the terms of a federal-provincial agreement, and in the following year drafted the Pacific Accord along the lines of the federal-provincial Atlantic Accords for Newfoundland and Nova Scotia. As part of this arrangement it was agreed that revenues from offshore hydrocarbon production would go to the province as if on land. However, since several important issues remained outstanding pending the opening of land claim negotiations and the establishment of management structures and procedures, the Accord remained incomplete. So, there is still no negotiated basis for legislation.

Further progress toward the lifting of the moratoria was postponed in the wake of two oil spills off the coasts of Washington and Alaska: the "Nestucca" barge spill in December 1988 at the western end of the Olympic Peninsula, and the "Exxon Valdez" tanker spill in March 1989, which spilled 40 million litres of crude oil in Prince William Sound off the coast of Alaska. Whereas the former was relatively minor, the latter was serious – indeed the biggest spill in U.S. history, though not of the same magnitude as the most catastrophic in other offshore regions. Lethal damage to marine mammals, sea birds, and certain species of fish and crustaceans was quite substantial in the area most directly affected. Some later research suggests that non-lethal effects on the ecosystem in adjacent areas were not as damaging or persistent as originally feared, except perhaps at the micro-organism level. However, the jury is still out on many of the long-term effects, and certainly the "Exxon Valdez" spillage had the result of reviving environmental fears in British Columbia. Although the damage was caused by a tanker grounding due to the captain's gross negligence, not to any offshore activity on the shelf, environmental concerns led to a "no drilling" ban, initially for five years.

By 1997 the local resource-based economies in and around Prince Rupert and Port Hardy were suffering severely from world market trends that seemed, and still seem, unlikely to prove reversible. Economic recovery in northern B.C. was – and still is – lagging behind most of the other provinces and could benefit significantly from the introduction of a valuable offshore industry. A local private sector group set up the North Coast Oil and Gas Task Force to advocate a B.C. government interim review of its moratorium policy. Meanwhile the Northern Development Commission was established by the Province to conduct extensive consultations on strategies for recovery of the northern B.C. economy, including the possibility of introducing new industries into the region. Through both of these private sector and public sector initiatives, mayors,

business representatives, and other community leaders have been actively engaged in renewal of the debate on the moratorium policy.

In the meantime, of course, scientific research of relevance to the increasingly public debate continues in B.C., as well as in the states of Washington and Alaska. This is especially true in fields such as seabird population dynamics, ocean current circulation patterns, ocean temperature variability, and persistent long-term effects of oil spills on low-order organisms. New offshore-related technologies are emerging, and the older ones are improving. In addition to learning from offshore experience elsewhere, Canadian government and industry can draw upon recent Newfoundland and Nova Scotia experience in the Hibernia, Sable Island, and other areas of the Northwest Atlantic. Moreover, B.C., unlike these other provinces, has a well-established petroleum industry on land with capacities and infrastructure available for application to offshore operations, and potentially for the development of sophisticated petrochemical industries. On the other hand, environmental concerns centred on fears of spills from tankers and pipelines continue despite technological improvements and the prospect of tighter regulations such as the requirement for double-hulled tankers, which will come into effect in 2001.

The Potential Value of the Resource

The offshore area in question lies in the Queen Charlotte Basin, beneath eastern Graham Island, and in offshore shelf areas of Hecate Strait, Queen Charlotte Sound and Dixon Entrance. The only way to find petroleum is to drill for it. Prior to extensive drilling operations, estimates of a petroleum resource are based essentially on geological surveys and on comparisons of resources extracted elsewhere in areas of similar geological characteristics. These scientific estimates are by no means “guesswork”, but they are tentative until the resource is a “proven” reserve through exploration.

At present, published geological surveys for the Basin (based partially on drilling experience, both onshore and offshore) indicate a resource potentiality ranging from 6.3 to 19.4 billion barrels (bbl.) of oil and from 12 to 489 trillion cubic feet (tcf.) of natural gas. In 1998 the Geological Survey of Canada (GSC) estimated the potentiality of the northern B.C. resource at 9.8 billion barrels of oil and 25 trillion cubic feet of gas. This basin is considered by geologists to be the most promising untapped resource along the northeast Pacific continental margin of Canada and the United States, comparable in magnitude to the Cook Inlet Basin of southern Alaska. If the GSC’s 1998 estimates are accurate, the Queen Charlotte Basin resource might be three times larger than the Hibernia field of Newfoundland. However, the complex geology and anticipated high exploration risks associated with the Queen Charlotte resource require a lot of seismic data to be assembled and many exploration wells to be drilled before a truly reliable evaluation can be made.

Using the usual median projections multiplied by the current (early October 2000) world prices, specialists estimate that the value of the oil could be as high as $55 billion (US) and that of the gas at $40 billion (US). The total “downstream” value of the resource, including the additional wealth that would be generated in, or attracted to, the region by the arrival of an offshore oil industry, could conceivably be close to $500

billion (US). Spread over a 30-year period or longer, the annual revenues to B.C. might, therefore, be as high as $3 billion (US) directly from production and $15 billion (US) in total "downstream" benefits.

These annual projections, if accurate, would make offshore oil and gas production the second largest industry in the Province, far behind tourism at $8.3 billion (US) annually but ahead of logging and forest products ($2.2 billion US), mining ($1.8 billion, US), agriculture ($0.8 billion US), and fishing ($0.2 billion US). Currently the onshore oil and gas industry of B.C. generates at least $0.68 billion (US) annually. On current estimates, offshore hydrocarbon development in B.C. might contribute 14% of the provincial G.D.P.

These figures assume that B.C. offshore oil and gas resources would be used as a fuel in the conventional manner. Some energy specialists argue, however, that these resources should be applied to non-fuel purposes such as plastics and other sectors of the chemicals industry, or in the case of natural gas provide the basis for a new fuel cell technology or similar purposes associated with a "hydrogen-based economy". In this way, it is argued, B.C. could become a world leader in the fashioning of the much-debated "new world economy", which would be more sustainable and less volatile than the oil-based economy, which has produced so many problems along with its benefits over the last 60 years.

Uncertainties, Time-frames and Sequences

Projections are, of course, notoriously unreliable. Especially in a context such as that of energy policy, it is difficult to capture the magic of accurate forecasting of world supply and demand. Today, moreover, the forces of economic interaction in the world market virtually preclude any safe assumptions about the role that the B.C. economy will play at the global level even ten years from now. In some highly volatile industries, such as mining, change is known to be cyclical, but it is extraordinarily difficult to predict the length of upward and downward swings in demand. In the case of the energy industry, the dynamics of consumption depends on numerous factors, including the unknowable outcome of current scientific research and technological innovation.

Current estimates of the potential value of B.C.'s offshore hydrocarbon resources are subject to massive uncertainties. Moreover, the processes and procedures of exploration, consultation, survey, calculation, preliminary assessment, regulation, approval, corporate decision-making, investment, logistical planning, installation, and other preparations for initial production are becoming increasingly protracted. Even if the federal and provincial governments decided "tomorrow" to lift the moratoria, it is difficult to envisage a start-up to offshore production in much less than ten years.

On the one hand, a lengthy 10-year period of preparation would seem to be the best way of ensuring the design and implementation of an "optimal production strategy" for B.C., based on the benefits of learning from experiences in other offshore regions, even though some delays that are inevitable elsewhere in the absence of a land-based petroleum industry might be avoidable here, where relevant experience is already at hand. An extended period of preparation is perhaps necessary especially in B.C., where negotiations with industry, the federal government, and First Nations claimants may be

difficult and protracted. Moreover, an extended preparatory period would be likely to produce considerable benefits for B.C. associated with interim activities such as seismic exploration, exploratory drilling, engineering design, environmental assessment, and other kinds of technical analysis. On the other hand, the longer the period prescribed for comprehensive preparation, the less likely the original projections of value, based on market demand, will prove accurate at the time of production. Experience elsewhere provides many examples of both underestimation and overestimation. Risks of miscalculation are unavoidable. With a drop in world oil prices or a rise in production costs, industrial incentive to invest in the B.C. offshore may decline quickly and decisively.

Even within the suggested 10-year time-frame for effective preparation, experts will differ on the best method of "sequencing" preliminary initiatives. If approval-in-principle were given by the B.C. government to the lifting of the provincial moratorium, should it be announced immediately so as to permit an early start to a comprehensive and rigorous process of preparation before final approval is given? Or should a great deal of preliminary work be done, or encouraged, before the government commits itself to a production policy? What point on the time-line is the most appropriate for B.C. to begin detailed consultations with the federal government, on the one hand, and with the industry, on the other? The crucial decision to invest in production is, of course, corporate, not governmental. If the B.C. electorate, the provincial parties, the government bureaucracy, and the affected local communities remain divided on the moratorium issue, the period of preparation may be further prolonged and effective negotiations with Ottawa, industry and First Nations further postponed. Prolonged delays and dissension on the West coast may have the effect of forcing industry to turn its back on the northern B.C. resource, and perhaps to concentrate instead on an even more substantial investment in the Arctic, where the local communities are now in agreement on the need for industrial development—or, indeed, elsewhere in the world, where such considerations may be irrelevant.

The outcome of the forthcoming B.C. election will no doubt have some bearing on whether a federal-provincial government consensus can be reached soon on the lifting of the moratoria, and on whether the governments can agree on a revenue-sharing formula comparable with the formulae adopted for the benefit of the less affluent provinces of Newfoundland and Nova Scotia, where the workings of equalisation provisions strongly influence the net outcome of such financial arrangements..

Environmental Impacts

Four phases of the offshore production process carry risks of environmental damage: during the preliminary seismic surveying of the potential resource; during rig installation and drilling; throughout hydrocarbon production; and in the course of transportation of the oil or natural gas.

The potential for impact from seismic exploration is limited to the duration of activity that may result in avoidance behaviour in adult fish and marine mammals. This could lead to long-term effects on larvae and eggs depending on the length of the survey and avoidance behaviour. However, since the industry's switch from use of chemical

explosives to air-gun percussion in survey work, toxic effects have been largely eliminated.

Depending on the type of rig, anchors may be used on the seafloor that will result in the loss of benthic epifaunal habitat under the anchor. However, the rig itself attracts fish, corals and other species that seek fixed structures for habitat. Drilling, both for exploration and production, has its largest impact through the discharge of drill muds and cuttings. In general, these materials are treated to remove formation hydrocarbons, those found in the rock being drilled, before being dumped. Advances in mud technology have led to additives that do not have toxic effects. The data collected, mostly from "Ekofisk" and other North Sea installations, shows clear chemical and physical disturbances only within the immediate vicinity of the rig: within a radius of 0.5 to 3.0 km.

Hydrocarbon production creates production fluid that is also treated but is by nature toxic. Further, blow-outs and spills do sometimes occur during drilling, as in the case of the recent Venture/Sable Island operations, but the severity of the impact depends on the nature of the hydrocarbon resource, the type of drilling operation, the local environmental conditions, and other factors. The chief environmental risk arises in the course of transportation, certainly in terms of probability though not necessarily in terms of potential severity.

The term "hydrocarbons" includes a wide variety of chemicals, with properties ranging from gaseous to solid state at normal environmental temperatures. Their characteristics include declining water solubility with increasing molecular weight, increasing resistance to environmental degradation with increasing molecular size, and, in general, increasing toxicity but declining bio-availability with increasing molecular weight and structural complexity.

Hydrocarbons are driven by their low water solubility to accumulate at interfaces: that is, at the sea surface (the air/water interface), at the sediment surface (the sea-bed), and on beaches (the water/land interface). Accordingly, the organisms that usually are most at risk and most obviously affected are those occupying interfaces, such as sea birds and mammals, which use the sea surface, and prawns, crabs, burrowing worms, and other species that occupy sea-bed and beach surface sediments. However, during a major spill hydrocarbons dispersed in the water column may be taken up by biota or may cause toxic effects.

In Eastern Canada there have been three significant examples of offshore damage in the last 30 years. In February 1970 the huge (100,000 ton) "Arrow" bunker oil spill in Chedabucto Bay in Nova Scotia was brought ashore by winds to the south-eastern area of Cape Breton Island. Shorelines exposed to wind and wave action were cleaned up in less than five years, whereas sheltered bays remained contaminated much longer. Toxicity was acute in local areas (that is, in areas close to the spillage site), producing chronic effects on the re-colonisation of certain species in the most heavily oiled waters.

In March 1979 the same area of Cape Breton Island and also southern Newfoundland were affected by wind-driven slicks from the "Kurdistan" bunker oil spill in Cabot Strait. But these slicks took several weeks to come ashore, and relatively little biological impact was observed other than to sea birds.

The other major occurrence in Eastern Canada took place in February 1984 at the time of the "Venture" gas/condensate blow-out near Sable Island. But the chemicals had a short "residence time" in the water column (several hours to a few days); no adverse biological effects were recorded; and no tainting of locally caught fish was observed.

Of these three incidents, only the "Venture" blow-out was directly related to offshore exploration. The "Arrow" and "Kurdistan" spills were associated with the transportation of bunker oil, a heavy oil that has undergone some processing. Since the 1970's, Canada has developed very stringent offshore regulations, but these were influenced not by the "Arrow" and "Kurdistan" accidents, but rather by the "Ocean Ranger" disaster in 1982. The "Ocean Ranger" was a production platform on the east coast of Canada that went down in an extremely heavy storm resulting in the loss of 84 lives.

Much research has, of course, been done on the effects of oil pollution in other offshore areas. In the North Sea there have been four major accidents in 33 years, though only the second of these was directly associated with offshore operations. In March 1967 the "Torrey Canyon" tanker casualty brought crude oil to the shores of Cornwall and Brittany, but the extensive use of detergents as dispersants is believed to have been more toxic than the oil itself. Re-colonisation by "stable or natural" communities, as distinct from "opportunistic" species, required approximately 10 years.

In April 1977 the "Ekofisk" (Bravo) platform accident spilled 20,000 tons of light crude into the North Sea, but the slick was dispersed rapidly by gales. The tainting of local fish was minor one month after the blow-out, and non-detectable three months later.

The huge, 220,000 ton spillage caused by the "Amoco Cadiz" grounding in March 1978 off the coast of Brittany caused extensive beach contamination, which persisted for several years and resulted in substantial damage to local oyster, crab and lobster fisheries. The benthic communities required over five years to approach full recovery level.

A fourth North Sea accident occurred in January 1993, when the "Braer" spilled 84,000 tons of light crude off southern Shetland. In this case again, much of the oil was dispersed by wind and wave action, as in the "Kurdistan", "Venture" and "Ekofisk" incidents. Sub-lethal biochemical changes in the local fish lasted only six months. On the basis of subsequent research, it appears that herring larvae in the wild are not adversely affected by spills, even though ambient hydrocarbon concentrations exceed those which cause sub-lethal effects in laboratory studies. However, after the "Braer" spillage real or perceived "tainting" destroyed the market for locally farmed salmon for a considerable time.

In short, experience in various offshore areas shows that every spill or blow-out has a different set of effects, depending on the type of hydrocarbon, the characteristics of the affected environment, and the prevailing weather conditions during and after the accident. Lighter hydrocarbons have shorter residence times and less persistence than heavier hydrocarbons. Since continental shelf ecosystems are highly variable in space and time, the "signal" of such effects may sometimes be difficult to recognise in the "noise" of natural variability.

Understandably, much of the concern about offshore hydrocarbon production focuses on the threat to local fisheries. Marine ecosystems are complex, and commercial fish are

usually close to the top of the food web. The severity of the ecological effect of a spill on the fisheries off the northern coast of British Columbia would depend not only on the kind and volume of hydrocarbon extracted, the mode of exploration and production employed, and the climate and weather patterns experienced in the region, but also on the location and characteristics of the species occupying the local interface areas. For example, pelagic species such as salmon, herring, tuna and mackerel, which are highly mobile and feed near the water surface, are usually the most unaffected by oil spills. Greater damage to fisheries can be expected in the case of less mobile, bottom-feeding demersal species such as cod, haddock, plaice, halibut and flounder. Oil pollution, therefore, poses a more serious threat to shallow-water groundfish stocks, such as those which constitute the bulk of the fisheries of Atlantic Canada, than to the stocks off the narrow shelf of British Columbia. Most at risk are benthic ("sedentary") species, including all molluscs and crustaceans, such as clam, oyster, scallop, crab, squid, lobster, and shrimp, and the eggs of many pelagic and demersal species which derive their food directly from the sea-bed, where hydrocarbon tends to accumulate after a spill.

In summary, then, offshore oil spill experience is variable, but perhaps the single, most important lesson to learn from scientific research of oil spills around the world is that most spills break up and disperse fairly quickly under wave and wind action during storm conditions or heavy seas. The greatest long-term damage is likely to occur when the spillage occurs close to shore and finds its way into shallow, congested, semi-enclosed coastal waterways, as was the case of the "Amoco Cadiz" spill. Even in such circumstances, however, damage appears to be fully reversed within a decade or two, a period long in social, but not in ecological, terms. With respect to routine operations, the most serious effects are within close vicinity of the rig, associated with drilling mud/cuttings, oily water dumping, and hydrocarbon transportation.

Risks: Facts, Perceptions, and Myths

Public policy issues that engage public attention often attract a wide range of concerned citizens as well as officials, experts, and diverse "stakeholders". In such cases public and semi-public discussions may reveal a confusing interplay of facts, perceptions, and "myths": that is, factually unsupported popular beliefs. Myths and perceptions may be "wrong", in some sense, and yet possess a social or political "legitimacy" because of the fears and other emotions that they reflect. The relevance of perception and myth to the public debate in B.C. on the offshore moratorium issue is particularly marked in the controversy over the risks involved.

For a number of reasons, risk assessment is a difficult, controversial and confusing science. First, the general public is often confused by references to high or low risk in a context such as offshore oil production if it is not explained that there are two very different aspects of risk: the probability that a spill or blow-out will occur and the severity of the consequences if it does occur. The probability may be low, but, in certain circumstances, the risk of severe damage may be quite high; or the reverse may be true. For example, offshore blow-outs can cause a lot of damage, but their frequency rate is very low. Atlantic Canada's only blow-out, at the "Uniake G-72" well off Sable Island in 1984, involved only 1,500 barrels of condensate. The United States has had only two

major blow-outs of greater than 50,000 barrels of oil: Santa Barbara in 1969 and "Tinbalier 26" in 1970. Of an estimated 150,000 wells world-wide, only five blow-outs have involved more than 150,000 barrels: Dubai (1973), Norway (1977), Ixtoc I (1979), Nigeria (1980), and Mexico (1986). Since 1988 there has been only one blow-out greater than 10,000 barrels: in the Gulf of Mexico in 1992. Statistically, the chance of a blow-out is small: one out of every 180 exploratory wells and one out of every 380 development wells. If ten wells are drilled in a year, there is a 0.05% chance of an extremely large spill (over 150,000 barrels) and a 0.15% chance of a large spill (over 10,000 barrels).

Second, experts differ on whether risk is wholly measurable and reducible to an objective "reality" through statistics, science, and technology, or is rather a complex psycho-cultural phenomenon that always consists in part of subjective elements. In a moratorium situation, a government may be reluctant to lift the ban because of its (or the electorate's) perception of risk, even though most of the experts may consider the risk inherent in production at a given site to be low. Ultimately, of course, the decision is a political one, influenced by the government's perception of acceptability in light of electoral sentiment as much as scientific fact and expert technical opinion. In such a context not all opinions are equal, but in a democracy, where everyone has a right to express an opinion, however ill-founded, "perception" or "myth" may sometimes prevail over "fact". For example, statistics on the probability of a blow-out off the Queen Charlotte Islands may not carry the day.

Third, it is sometimes argued that different "cultures" not only perceive risk in different ways, but also vary in their tolerance of risk. A highly protective, conservationist culture will "see" risks differently from a more entrepreneurial, individualistic culture. As discussed below, variations in risk tolerance within the same culture may be perceived as ethical in significance. Traditional coastal communities, such as the Haida communities of Queen Charlotte Sound, with a culturally conditioned reverence for nature, may find it difficult to be "pragmatic" about orders of probability of blow-outs.

Moreover, the risks involved are not exclusively environmental in nature. There may also be a risk that the projected socio-economic benefits turn out to be an "over-expectation", or limited to a shorter term than anticipated. Geological estimates may be inflated by hopes within the industry. The main fear of the local community adjacent to offshore hydrocarbon resources is usually that most of the economic benefits will pass through and end up in a corporate "pocket" outside the area, or even outside the host country. Ideological resentment against transnational corporations and other powerful agents of capitalism may result in a widespread distrust of the oil industry as a whole.

Experiences of offshore hydrocarbon production – and many other examples of foreign capital investment – have, of course, provided a mixture of effects, both positive and negative. The worst cases certainly give credence to fears of "pass-through", or "leakage": that little of the wealth generated will accrue to the local community beyond the initial period. But this belief is a "myth" if it ignores the evidence that good planning can and does avert this inequitable outcome. It should be understood in B.C. that Norway, Scotland, and now Atlantic Canada, have all found it possible to keep a reasonable proportion of the economic benefits at the local community level. In all three regions, the significant enrichment of the local communities as a result of offshore development is visible to the visitor, and is statistically verifiable, although it is

admittedly too early to predict that local enrichment in Newfoundland and Nova Scotia will match that in the North Sea countries. In the meantime, northern British Columbians with "pass-through" fears might wish to study the case of Shetland, which has prospered dramatically since the arrival of the offshore industry, due not least to the government's local hiring and local control policies.

As to the risk of social disruption due to the arrival of an offshore industry, there is evidence to support the view that new affluence can attract certain kinds of disorder, not least as a result of the influx of newcomers and the clash of lifestyles. But the threat to traditional culture can be averted. In the case of Shetland, the exact opposite of what was feared has come to pass because the local council put oil revenues into enhancement of traditional arts and crafts. A significant rise in crime is by no means inevitable, as shown again in recent Scottish and Norwegian studies, if the population as a whole tends to be law-abiding. Moreover, the incoming industry itself has an interest in contributing to the social welfare of the local community, which may be the principal source of its labour force. There is no doubt that at least in the case of southern Norway and northeastern Scotland the local communities have gained very substantial improvements in their standard of living as a direct result of their offshore economy. The key requirement is, of course, good leadership and effective planning based on consultations with the government agencies, companies, experts and communities most directly affected.

In a "new risk" area, negative perceptions and myths must always be countered by factual evidence based on relevant experience elsewhere. Since the Queen Charlotte Sound region is similar in many ways to Cook Inlet off the coast of Alaska, it should be noted that this offshore area has apparently not suffered any serious adverse effects from three decades of offshore petroleum activity. The Alaska Oil and Gas Association points out that even Greenpeace has been unable to find any evidence of oil-related contamination in these waters, which support important commercial and sport fisheries – a claim that apparently is unchallenged. On the other hand, the Association is hardly an objective source and more research into long-term effects in the Inlet is needed before its opinion can be endorsed.

A recent U.K. report (Oil and Gas in the Environment), published in 1998, shows that the environmental impact of offshore oil production in the North Sea has declined significantly since the 1980's. "The amount of oil discharged in drill cuttings has been reduced substantially and, whilst this is offset to some extent by the amount in production water, the load of oil is very much reduced overall. According to the industry records, the quantity of oil spilled from the platforms has also decreased, although production still accounts for a significant proportion of oil inputs into the North Sea." The greatest tonnage is carried by pipeline, with little environmental impact, and the number of spillages from tankers declined considerably between 1974 and 1984, accounting now for only 0.1% of inputs into the North Sea. In fact, the biggest environmental pressure related to oil and gas is from the use of gasoline and diesel in transport.

Yet, irrational or not, fears remain that the risks involved – environmental, economic and social – are too great to be acceptable. Focussing on the worst-case scenario, which does admittedly sometimes occur, may nevertheless prove unnecessarily alarmist.

Nuclear war did not erupt between the Soviet Union and the United States, but the danger of smaller-scale nuclear wars is still with us, justifying campaigns against nuclear weapons. Nuclear plants have a very good environmental safety record where technological standards are high, but Chernobyl did happen, and might happen again elsewhere, justifying calls for the strictest possible controls on design, construction, maintenance and inspection of nuclear facilities. The offshore oil and gas industry of B.C. must follow suit.

Politicians have a responsibility to be aware of legitimate fears in society, including fears of possible blow-outs and major spills in the offshore. But preventing offshore production in B.C. does not, of course, eliminate the risks in the industry; it simply displaces them elsewhere. Proponents in favour of lifting the moratoria sometimes argue that displacement from a high-standard environment such as B.C. may simply deflect offshore operators to other places with lower standards, where the probability of a serious accident is higher. By this reasoning, put in global perspective, the moratorium policy in B.C., which is justified by reference to risk, reflects a local NIMBY ("not in my back yard") attitude, and may actually increase the risks of offshore accidents!

Finally, it should be noted that the risks of misadventure can be reduced greatly by the development of a high-quality regulatory regime, including a tested contingency plan that requires the effective integration of oil spill response teams representing the best capacities of the Canadian federal and B.C. governments and private sector specialists as well as their counterparts in the states of Washington and Alaska. Similarly, risks can be reduced by ensuring effective environmental assessment policies and procedures before project approval and effective post-approval monitoring programmes. So the greater the fears, the more important it is to put the best resources available into the preparations that would precede production. It is an axiom of international environmental policy - and now generally accepted by industry - that all reasonable precautions should be taken before proceeding to any large-scale initiative that could be harmful to the natural environment and to the resources upon which local communities depend.

The Economics of Hydrocarbon Production

There is certainly a market for B.C.'s offshore hydrocarbon resource. Indeed there are two, because the market for oil is quite distinct from that for natural gas. The market for oil is global, and the price is not driven by what happens locally. Gas, on the other hand, has local, regional or continental markets. Gas prices here rise and fall with fluctuations in the North American market. Almost certainly, natural gas extracted from the B.C. offshore would be exported to the United States, probably to the Chicago hub where there is unsatisfied demand, or to California, depending on delivery costs.

Experts differ over the future rate of growth of world demand for crude oil. A recent forecast by the U.S. Energy Information Administration has envisaged a jump from the current level of 76 million barrels per day to 117.4 million barrels per day by the year 2020. This estimate reflects heightened expectations for oil demand in the United States, the Middle East , the former Soviet Union, China, and the Pacific Rim developing countries. World supplies of oil are expected to grow by 2.2% annually, falling slightly

short of demand over the next two decades, according to the same source. Over this period U.S. oil production will continue to fall at an annual rate of about 1%.

Many estimates of future oil demand are influence by expected changes in the Chinese market. Until the 1990's, China seemed to have plenty of crude oil in domestic reserves, especially in the northeastern region. But in 1993 China became a net importer of oil, taking advantage of low prices in the world market, and today foreign crude oil accounts for one-third of the output of Chinese refineries. Most projections of future Chinese demand for oil over the next 20 years are based on the assumption that Chinese development will result in an enormous increase in the use of vehicles even in the face of sharply rising oil prices.

However, environmental concerns associated with the overuse of oil suggest that natural gas rather than oil is more likely to be the preferred fuel of the future. The potential demand for natural gas is particularly huge in Asia, where a number of industrialised and industrialising countries have been moving away from oil as the primary fuel source for their commercial and public service sectors since the oil crises of the mid-1970's and early 1980's. In Asia (excluding China and Japan) natural gas is the least used fuel, but its growth potentiality is enormous if delivery problems can be overcome. Japan and to a lesser extent South Korea and Taiwan already import liquefied natural gas (LNG) by tanker, making Asia the biggest LNG-importing continent, despite the fact that Indonesia, Brunei, Malaysia and Australia export LNG within the Asia-Pacific region. At present the only transnational gas pipeline in Asia is between Malaysia and Thailand, but other cross-border pipelines are being planned as part of the proposed Trans-ASEAN Gas Pipeline for Southeast Asia.

On the face of things, there is a big market for the export of Canadian natural gas to China. The share of gas in the PRC's total energy consumption is very small, because the natural gas reserves in that country are modest in size and lie in remote areas. Soft coal, on the other hand, is superabundant and extremely cheap, making it difficult for PRC decision-makers to spurn the bounty of nature despite compelling environmental reasons to reduce the level of industrial pollution. It is still difficult to predict whether international pressures on China to reduce its emissions (which, incidentally, drift over British Columbia) will prove successful. On the whole, it seems more likely that natural gas from the offshore B.C. reserve, despite the rising Asian demand, will be piped down to California or otherwise stay within the North American market.

Most experts expect world oil prices to remain "high": that is, around or above $30 U.S. per barrel. Indeed almost all economists deplore the goal of "cheap oil" on economic as well as environmental grounds. Moreover, experience has shown that governments are extremely reluctant to lower the high taxes on gasoline and other oil products, given the huge revenues available and the proven fact that demand for these products is not very responsive to price. So apparently it could be expected that B.C.'s offshore oil will bring in substantial public as well as commercial revenues over the next two or three decades.

Clearly the impact of offshore production on the B.C. economy would be mostly positive. Given the estimates offered above, the new industry would generate many much-needed jobs and substantial new income; directly, indirectly, and over time. In addition to the exploration, development, production and downstream benefits to the local or regional economy – associated with Regional Districts 49, 47, 45 and 43 – there would also be

net positive spillover effects to other regions within the province: for example, non-local purchases of capital equipment and supplies, outside expenditures by resident income earners and in-commuting labour, and government revenues in the form of taxes. A guaranteed local supply of hydrocarbon should create somewhat lower energy prices than would otherwise prevail. Moreover, offshore production would create miscellaneous, intangible economic benefits in various forms: for example, increased competitiveness of local firms and improved services in such sectors as communications, environmental information gathering, weather forecasting, and emergency response.

On the negative side, there will be some adverse impacts on other sectors. Commercial fisheries will be excluded from zones around the rigs and platforms; seabed debris will accumulate; and the costs of shipyard and harbour space and other marine services could be expected to go up. Conceivably, but not necessarily, there may be losses in aboriginal and recreational fisheries, tourism and forestry (from which skilled labour may be siphoned off to better-paying employment on the rigs and platforms). Oil spills would, of course, affect various forms of sea-life and, at least temporarily, spoil the pristine beauty of the shoreline. At least in the short term, offshore activity will cause inflation in the local economy including the real-estate market. There may also be social dislocation costs, though elsewhere, as noted above, these have been less serious than originally projected.

Most of these benefits and losses are, of course, difficult to quantify at present, but a large-scale, 5-year national research project ("Coasts under Stress"), linking B.C. with Newfoundland and Nova Scotia, is designed in part to produce estimates of these economic and social impacts.

The Northern Development Challenge and the Search for Consensus

In October 1997 the provincial government brought together business owners, investors, community representatives, and representatives from all economic sectors to discuss northern economic issues and potential opportunities for future job creation. One of the outcomes was the recommendation that an agency should be created which would be devoted to enhancing communications between people of the north and the government in Victoria. With the passage of the *Northern Development Act*, in July 1998, the Northern Development Commission was created.

The Commission's mandate is to act as an advocate for northern development; to encourage private sector investment in the north; and to work with groups and organisations involved in economic development. With a view to transforming the local economy in the Prince Rupert area, there is recognition that the traditional logging and fishing industries are in decline. In response to requests from northern British Columbians, the Commission has undertaken a series of consultations with all stakeholders on the prospects of offshore oil and gas development. A Conflict Managers Group was contracted to facilitate these consultations.

On July 31st, 2000, these consultants submitted their report, emphasising the importance of adopting a broad approach to the consultative process. Such an approach extended beyond the local (Queen Charlotte Basin) area to various institutions in

northern Vancouver Island, representatives of industry, environmental groups and, of course, provincial and federal officials. The consultants reported that the northerners consulted wanted "access to credible and authoritative information concerning the present state of oil and natural gas ocean drilling and production technology, including studies or reports that have examined the economic, social and environmental impacts of bringing on stream the East Coast operations, as well as those in the North Sea". Many of those consulted believe it is particularly important to become informed about the regulatory regime constructed by the provincial and federal governments to deal with environmental assessment and resource management issues.

The lesson learned from these preliminary consultations is that the northern coastal community wants to participate in a community-based consensus-building process, not least to reach agreement on the moratorium issue. The consultants recommended the establishment of a "process design group" consisting of 10-12 persons selected from "the different groups that make up the larger coastal communities, such as local and regional government, First Nations, small business, larger business, fishers, environmentalists and the general public". A consensus process is defined as "one in which all those who have a stake in the outcome aim to reach agreement on actions and outcomes that resolve or advance issues related to environmental, social and economic sustainability". Although not all participants may agree on all aspects of the agreement, consensus is reached if they are willing to live with the compromise reflected in the "total package". Responsibility for collecting the appropriate information for consensus-building purposes may be entrusted to the University of Northern British Columbia.

It is hoped that the consensus-building process will be completed by the spring of 2001, so that final recommendations on the offshore issue can be submitted by the Commission to the Minister Responsible for Northern Development by July 2001.

The Political Environment of B.C. Offshore Development

The political environment within which the offshore issues must be resolved is a "stakeholder environment", largely governed by consensus-building initiatives and outcomes of the kind described above. But consensus within the affected local communities is only the first step in a series of what may prove to be difficult and protracted efforts to achieve much broader agreement involving a dozen or more ministries and other agencies, federal and provincial, including the National Energy Board, and at least one of the major permit holders (probably Chevron). There is no single repository of "political will" that can determine the outcome.

The "stakeholder environment" of B.C. is in robust health. On matters such as the offshore moratorium issue, B.C. is a lively and rather sophisticated example of "governance beyond government". The extent and depth of "civil society" involvement in this public policy controversy certainly complicates the decision-making process, which is already complex at the government level due to federal-provincial structures and procedures and the weight of regulatory requirements. But at the end of the consultation processes envisaged here, most British Columbians are likely to be satisfied, whatever the outcome, that the process was appropriate, conducted in accordance with contemporary standards of participatory as well as representative democracy.

Other environmental-economic controversies, such as the asbestos issues in the U.S. and logging issues in Canada, have shown how difficult it can be to reconcile the competing interests and values associated with shareholders and jobholders, on one side, and with "stakeholder democracy" within the general social context. Antagonisms sometimes necessitate the introduction of a "mediating force" of some kind to identify trade-off possibilities and to explore modes of compromise that might be unlikely to occur to negotiators responsible for maintaining status quo "positions". Successful mediating under conditions of acute adversity may require the participants to "transform" themselves before there is any hope of compromise as the basis of consensus.

The importance and sensitivity of land claims by First Nations add to the difficulty of achieving compromise and consensus on the offshore moratorium issue. As a matter of federal government policy, "self-government" is a guaranteed, if constitutionally undefined, principle relevant to land claims, but not conceded to apply to areas such as the offshore, which comes under federal jurisdiction. Yet the political climate of distrust generated by difficult land claim negotiations is likely to spread to consensus-building efforts on the moratorium issue. The age of First Nations representatives is declining, and their relative youth is sometimes accompanied by impatience. Time may be short; shorter than what is required for effective consensus-building, comprehensive regime-building, and systematic planning. Experience with land claims might suggest that a final settlement on all the details of offshore development is unlikely without demonstrations and some degree of political confrontation. The danger is excessive expectations.

On the positive side, all participants are likely to agree on the critical importance of reliable information. Some of the political confrontation over the B.C. offshore is likely to focus on the "facts". Not everyone will accept that sufficient reliable data is available, much less agree on what constitutes "objective" analysis or interpretation of the data. So it must be hoped that most of those engaged in consensus-building will trust in the integrity and disinterestedness of those experts qualified to provide the facts, even if they are perceived as an elite outside the affected local communities.

Experience with other environmental and indigenous issues seems to reveal what has been called the "paradox of noise": as efforts at compromise and consensus progress, pulling more and more participants into a position of moderation and accommodation, the "noisier" the extremists on both sides become. To those outside the process the "noise" gives the false impression that the diplomacy has failed or is faltering, whereas the truth may be that the rising volume of dissent reflects the dissenters' awareness that they are being marginalised by the moderates who have captured the consensus-building process and are approaching success.

Other Aspects of the Controversy

There are other questions to be addressed: questions that may colour the tone of the consensus-building process, and even affect the design of consultation strategy.

A. *What is the Common Interest?* Virtually all of the intended participants in the projected consensus-building process in northern B.C. are representatives of "special

interests". Taken together, these participants still do not add up to the "common interest", which in a democracy such as ours is the foundation of public policy. Proponents of representative democracy argue that the traditional system of electoral government is the best guarantee of public policy based on common interest, since all voters have an equal voice during elections and have freedom of access to their elected representatives between elections. Critics of representative democracy argue that elections are too remote from most issues to provide popular control over decision-making, that government bureaucracies are even less amenable to the will of the electorate, and that a culture of "participatory democracy" needs to be nurtured through the constructive engagement of citizens' groups and special interest associations. Ideally, what is needed is a combination of the best features of both modes of democracy at all three levels of modern "governance": local/regional, provincial, and national. Only in this way could a decision on the B.C. offshore moratorium issue be said to rest on "common interest".

B. *Is There a Moral Dimension?* Those in favour of lifting the moratoria tend to frame their case around the interests of those who have a stake in the outcome. This argument assumes that benefits may outweigh costs, and that both are shareable on an equitable basis. It is "moral" to the extent it emphasises the value of equitable sharing. Many of those opposed to the lifting of the moratoria, on the other hand, are more inclined to see the issue within a framework of competing values or ideologies. Some of them consider themselves to be engaged in a political struggle against capitalism in general, or against the oil industry in particular, which they regard as a culprit industry responsible for environmental damage around the world. From this position it can be urged, as a matter of public morality, that hydrocarbon resources should be applied to non-polluting, or less polluting, non-fuel purposes through the chemicals industry, or to the development of a sustainable, morally superior, system of energy production. Related to this is the moral argument that the resource should be left in the ground for the benefit of future generations, particularly in the hope that they will be in a position to apply more sophisticated technology, so as to extract benefits without any damaging consequences. Similarly, the moral response to the "NIMBY" aspect of the problem is that hydrocarbon to meet global demand will come from somewhere. So, is it fair to expect another community to carry the costs, particularly one which may not have the stringent regulations that B.C. and Canada do? First Nations invoke special privilege or moral entitlement in furtherance of their own special interests, implying that the morality of affirmative action should outweigh the morality of equal treatment. Claims to the right of "self-government" for the indigenous peoples of Canada have been accepted by the federal government, as a matter of policy, as legitimate, along with the judicially approved concept of "aboriginal title", for purposes of negotiating land claim settlements, but it is certain that the offshore moratorium consensus-building processes and the negotiations that follow will also be influenced by the moral/legal principle of special entitlement.

C. *Is the Moratorium Issue Amenable to Mediation?* Resorting to a process of public consultation for consensus-building purposes is a principled approach to an eventual decision on the moratorium issue. But it will not be easy. Experience with cognate issues in B.C. suggests that it will be emotional and protracted. It may be that moderates can be drawn into a majority middle position favouring a comprehensive

program of preparations as a condition for lifting the moratoria, or at least for governmental approval-in-principle. It must be questioned whether this is likely to be achieved without the benefit of some kind of mediation service, under the auspices of the Northern Development Commission or otherwise. A widening array of professional mediation techniques is now available to draw upon in the B.C. "stakeholder environment". It is conceivable that certain difficulties will arise in the course of the initial consensus-building exercise that cannot be resolved until non-local participants become engaged, such as key provincial and federal government ministers and officials and oil industry representatives (e.g., Chevron executives). Only time will tell what a skilfully mediated consensus-building process can accomplish at the local/regional level.

D. *Will Constitutional Prerogatives Prevail?* Among constitutional lawyers, Canada is internationally conspicuous for its ingenuity over the years in finding ways of circumventing the division-of-powers language in its constitution. Few, if any, federal states can match Canada's record in finessing such settlements, prescribed in 1867, with flexible federal-provincial arrangements for the sharing of costs, revenues, responsibilities and services. Some of these arrangements are negotiated with all provinces together, others with only one or two or three deemed to be in a position of special disadvantage. The offshore Atlantic Accords with Newfoundland and Nova Scotia are in this latter category – especially the former. Presumably the draft Pacific Accord negotiated with B.C. several years ago represents only a partial approach to these key issues of sharing. Presumably also the federal government has not yet shown its hand on these issues, pending the B.C. government's decision on the possible lifting of its moratorium. There seems little doubt among Canadian constitutional lawyers that the offshore seabed areas in and around Queen Charlotte Basin fall within the domain of federal jurisdiction, and it must be supposed that this gives Ottawa an advantage over Victoria in the negotiation of a sharing arrangement. The federal government may not wish to match its generosity to Newfoundland on offshore hydrocarbon development, and it may be unlikely that the B.C. government would expect this. The only safe prediction is that the matter will be decided chiefly on a political level in the aftermath of the pending provincial election.

E. *Is B.C.'s Coastline Under Stress?* A large-scale nation-wide research project on "Coasts under Stress" involving universities in Newfoundland, Nova Scotia and British Columbia has just begun. It is designed to compare various kinds of threats to the coastlines and coastal communities of all three provinces, including threats associated with offshore hydrocarbon exploration and production. This project will provide the first opportunity for Canadian researchers to analyse systematically the status of coastal communities and the natural resources on which they are dependent under the conditions of industrialisation. Within this framework the teams will study many of the factors referred to in this paper. It may be expected that clear answers will become available on questions of net gain and loss to the coastal communities of Canada when priorities have been set in situations of conflicting ocean uses. In particular, it may be hoped that actual outcomes of resource-related decisions will be compared with pre-decision fears and perceptions of risk. Not least, the scientists engaged in this project will bring together for the first time a complete set of data for evaluation of Canada's coastal waters as the basis for

recommendations on more effective, "integrated" coastal zone management in accordance with the new Oceans Act of Canada.

Summary

Over the fifty-year history of offshore oil and gas in British Columbia, seismic lines have been shot, wells have been drilled, estimates of resources and their value have been made, and discussions at the tables of government, industry and the communities have been held. However, throughout most of this time and continuing today, moratoria put in place by both the provincial and federal governments have prevented exploitation. Now, perhaps, memories of the spill mishaps of the late 1980s have faded and the new developments on the eastern continental shelf of Canada and the economic plight of northern BC have resulted at least the first invitations to return to those tables in the hope of resolving the moratorium issue.

The resource has been valued in the tens of billions of dollars in direct and downstream value to the province of British Columbia. Used wisely, this revenue could form the support for a more dynamic, less resource-based economy in B.C. However, this estimate is subject to uncertainties. It could be a decade after lifting of the moratoria before start-up of the industry, during which time local and global economies can change dramatically. While this time before the lifting provides the opportunity to insure that the best available practices and technologies will be used, the longer B.C. waits, the greater the potential that the original value projections will be off and the industry will lose interest. In the end, even when the moratoria are lifted, the decision to go ahead is purely one to be made by industry. Delays have already forced the industry to look elsewhere. There are no assurances that its interest will return.

The moratoria were put in place mainly due to fears of devastating environmental impact. While some of the issues have been addressed by industry and technological improvements over the last couple of decades have made the industry much cleaner and safer, risk will always exist, as it does in any industry that exploits the natural environment. Most of the risk from routine operations arises from the release of drilling muds and cuttings as well as production water into the water column. Canada's regulations governing these aspects of the industry are strict, and getting stricter, and the effects from these activities tend to be localised and short-term. Perhaps the greatest danger, by sheer magnitude of effect, is the risk of oil spills from either a blow-out or during transportation. It is difficult to estimate a quantitative risk for such an event, since the magnitude of effect will depend not only on the type of hydrocarbon, but also on the physical environment and weather conditions.

Suffice to say, even with the best practices, technology and regulations, adverse effects are possible, even likely. The risk of offshore oil and gas is perhaps intangible because of differences in perception and tolerance for the probability and severity of routine and accidental occurrences. While the probability of an oil spill may be low, its severity is high and this fuels a perceived high risk involved with offshore oil and gas. Further, risk is not only a matter of the environment, but also falls in the realm of socio-economic effects. Experiences elsewhere around the world have been both positive and negative. However, good planning and learning from past experience should allow for prevention

of “leakage” of wealth out of the local economy and prevention of social disruption by both the community and the industry. If the offshore industry in B.C. is ever to advance, public fear must be alleviated by imposing controls on design, construction, maintenance and inspection of the offshore oil and gas industrial facilities and practices. There is a further need to ensure that high-quality contingency plans are in place with cooperation between the federal and provincial governments and industry as well as private specialists.

The industry has the potential to generate jobs and income directly, indirectly and over time within the immediate vicinity of the region, throughout B.C. and even across Canada. However, there will be some adverse impacts on other sectors such as restrictions on commercial fishing, increased marine service and supply demand, increased vessel and aircraft traffic as well as the potential for losses to aboriginal and recreational fisheries, tourism and forestry. It is possible though to use the experiences of Newfoundland, Nova Scotia and in Cook Inlet of Alaska to predict and mitigate effects. There is a market for this potential resource; it is a matter of balancing the potential negative effects with the positive.

Declines in the resource-based economy of northern B.C. have led to the creation of the provincial Northern Development Commission and the indigenous North Coast Oil and Gas Task Force. Preliminary consultation by the Commission showed that northern coastal communities want a community-based consensus-building process to decide on the moratorium issues. However, the structure of such a process is unclear. Also of particular relevance is the dimension that is added by native land claims in the region.

It is obvious that the issues surrounding offshore oil and gas in B.C. are controversial and will not be resolved easily. Many questions remain. What should be the roles of special interest and common interest in the consensus-building exercise? The issue of whether or not to lift the moratoria really requires a combination of representative and participatory democracy, but how is this to be accomplished? The overall issue is framed around competing, and often opposite, values and ideologies that include altruism, sustainability, environmental protection, and special entitlement of indigenous peoples but equal treatment within the larger society. Reconciliation of such competing ideas will be complicated and probably protracted. In fact, the issue may require more skilful and professional mediation along with consensus-building to achieve resolution. First, however, political agreement must be reached regarding provincial-federal arrangements for the sharing of costs, revenues, responsibilities and services. It is clear that this cannot be accomplished until after the pending elections. Hopefully research initiatives such as the national “Coasts Under Stress” project will help to answer some of the pressing questions and suggest solutions.

The issues surrounding the offshore oil and gas industry and moratoria of British Columbia range from uncertainties in value and resource estimates, the potential for environmental impacts, the perception of risks and its surrounding myths, the potential for economic and social impacts and the search for consensus. Perhaps it was wise of the governments to postpone decisions on such a controversial topic by placing moratoria on potential exploitation. The gains in knowledge and experience in the last decades of offshore exploitation will surely result in more efficient and safer extraction of the resource if it is to go ahead. However, the longer the moratoria are in place, the harder it

is to take them off and the less interested industry will become. British Columbians have a difficult decision to make, and a long road to traverse to get there.

Appendices

A1 Historical Timeline

1961 – Shell Canada Ltd. acquired federal oil and gas exploratory permits in the offshore of British Columbia (see map for federal exploratory leases).

1963 – Exploration surveys begun by Shell Canada including mapping of seafloor geology, aeromagnetic and seismic surveys in the area.

1967-1969 – Eight wells drilled by Shell Canada in Hecate Strait and Queen Charlotte Sound. Four of the wells showed signs of oil and gas, albeit the showings were minor and not considered significant.

1970 – A farm-in agreement was made between Shell and Chevron Canada Resources Ltd. such that Chevron would take over Shell's offshore area permits for oil and gas exploration.

– British Columbia moratorium on oil and gas exploration in the Juan de Fuca and Georgia Straits.

1972 – Last private sector seismic survey performed by Chevron.

– Federal government imposes a moratorium on crude oil tanker travel from Valdez, Alaska through Dixon Entrance, Hecate Strait and Queen Charlotte Sound. Following this, a federal Order-in-Council prohibited further exploratory drilling in these same waters for an indefinite period.

1978 – Geological Survey of Canada estimates potential reserves at 150 million barrels of oil and 6 trillion cubic feet of natural gas.

1981 – The provincial government of British Columbia reinforced the federal moratorium, also for an indefinite period. These moratoria effectively eradicated private sector sea floor exploration offshore of British Columbia.

1982 – **January** – Petro-Canada successfully completes negotiations with the federal Department of Energy, Mines and Resources for three blocks of exploratory permits in the area of interest.

– Chevron, seeking renewal of exploratory activity in Hecate Strait and Queen Charlotte Sound, prepares an initial environmental evaluation (IEE) for the federal Canada Oil and Gas Lands Administration (COGLA).

1983 – **July** – Petro-Canada Inc. submits their IEE to the federal and provincial government, also as part of a proposal to renew oil and gas exploration in the area of interest.

– **September** –Federal Minister of Energy, Mines and Resources and British Columbia Minister of Energy, Mines and Petroleum Resources sign an agreement to undergo a public review of the potential effects of offshore oil and gas exploration north of Vancouver Island using the previously submitted government and industry IEEs as background information. Consideration was to be given to the social and economic effects of offshore exploration as a preview to any consideration to lifting the federal and provincial moratoriums. The review was undertaken by an

independent panel made up of five members accepted by both governments, with each government choosing two of the members and the chairperson chosen by cooperation.

– British Columbia Ministry of Environment submits their IEE in response to the proposal from Petro-Canada and Chevron to renew oil and gas exploration in the offshore of British Columbia.

1984 – **January** – Approximately 80 social and environmental scientists from both the provincial and federal government and invited non-government were convened to conduct a rigorous evaluation of the IEEs presented by Chevron and Petro-Canada.

– **June** – Federal and Provincial Ministers of the Environment appoint the five members of the West Coast Offshore Exploration Environmental Assessment Panel to conduct the public review.

– **July** – Background documents available for public review.

– **September** – Public was asked to make suggestions for additional information that would be useful for the public review.

– **October** – The panel requested additional information from government, Chevron and Petro-Canada to supplement the IEEs.

– **November** – Petro-Canada withdrew from the public review process.

– Panel held public information meetings in Vancouver, Victoria and 14 north coast communities in order to allow Chevron to describe its proposed offshore exploration program and the Panel its review mandate.

1985 – **February** – Additional information is provided by Chevron, federal and provincial government agencies.

– **March and April** – Workshops were held in a number of northern communities in order to encourage participation in the public hearings.

– **September to November** – Panel hearings held in eighteen communities in mid and northern BC and Vancouver Island, Victoria and Vancouver.

1986 – Panel review document outlining the public review process and the resulting recommendations before exploration be allowed.

1987 – Negotiations begin between the federal and provincial governments towards the Pacific Accord which would detail arrangements for sharing revenue, costs, duties and responsibilities in the B.C. offshore.

1989 – **March 24** – Oil tanker *Exxon Valdez* strikes a reef in Prince William Sound Alaska spilling 11,000,000 gallons of crude oil through its ruptured hull.

– Alaska, Washington, Oregon, California and British Columbia sign a Memorandum of Cooperation to create the States/BC Oil Spill Task Force. Aside from holding regular meetings, the group sponsors working groups with other agencies, industry and interested non-government organizations.

1992 – Science Council of BC's Spark Oceans committee reports that data on the hydrocarbon potential is insufficient but that potential for significant reserves of oil and gas is present.

1995 – Geological Survey of Canada revises estimates to 2.6 billion barrels of oil and 20 trillion cubic feet of natural gas.

1996 – Canadian Ocean Frontier Initiative (COFRI) conference in Prince Rupert BC urges further investigation of the potential for offshore oil and gas exploration and move towards lifting the moratoria.

1997 – North Coast Oil and Gas Task Force is created by a group from Prince Rupert with the mandate to research BC's coastal communities economic future and its primary objective to have the moratoria lifted.

1998 – Geological Survey of Canada revises estimates to 9.8 billion barrels of oil with a gross revenue of $295 billion over time and 25.9 trillion cubic feet of natural gas with a gross revenue of $5.2 billion over time. Provincial royalties are estimated to potentially surpass $45 billion.

2000 – **May** – Workshop on the oil and gas moratoria is held at Simon Fraser University in Burnaby, B.C. Attended by industry, government, academia, native community representatives, environmental groups and the public, the workshop provided an open forum to talk about the issues and advances since the last public forums of the mid-1980s.

– **October** – Workshop on the oil and gas moratoria is hosted by the Maritime Awards Society at the University of Victoria's Dunsmuir Lodge in Victoria, B.C. Closed to the public, the meeting is attended by federal, provincial and northern community government representatives and invited academic participants to discuss the issues surrounding the moratoria that should be brought into potential future public forums.

A2 Statistical Summary

Input of Petroleum Hydrocarbons into the Marine Environment

Tanker Transport	45.2%
Municipal/Industrial Wastes and Runoff	36.3%
Atmosphere	9.2%
Natural sources-seeps, erosion	7.7%
Offshore industry	2.5%

Offshore Industry Blowout Statistics

Canada 1966-1995
- Uniake G-72 Well Sable Island 1984 1500 barrels of condensate

US 1955-1993
- Only two medium blowouts greater than 50 000 barrels of oil. Santa Barbara 1969 and Timbalier-26 1970.

Worldwide 1955-1995
Of an estimated 150 000 wells:
- Only 5 blowouts greater than 150 000 barrels. Ixtoc 1 1979, Dubai 1973, Mexico 1986, Nigeria 1980 and Norway 1977.
- Only one blowout greater than 10 000 barrels since 1988. US Gulf of Mexico 1992 Timbalier Bay 11 500 barrels.

Source: S.L. Ross Environmental Research 1995

Chance of Blowout

- 1 in 180 exploratory wells blow
- 1 in 380 development wells blow

If 10 wells are drilled in a year,
- 0.05% chance of an extremely large spill (> 150 000 barrels)
- 0.15% chance of a large spill (>10 000 barrels)

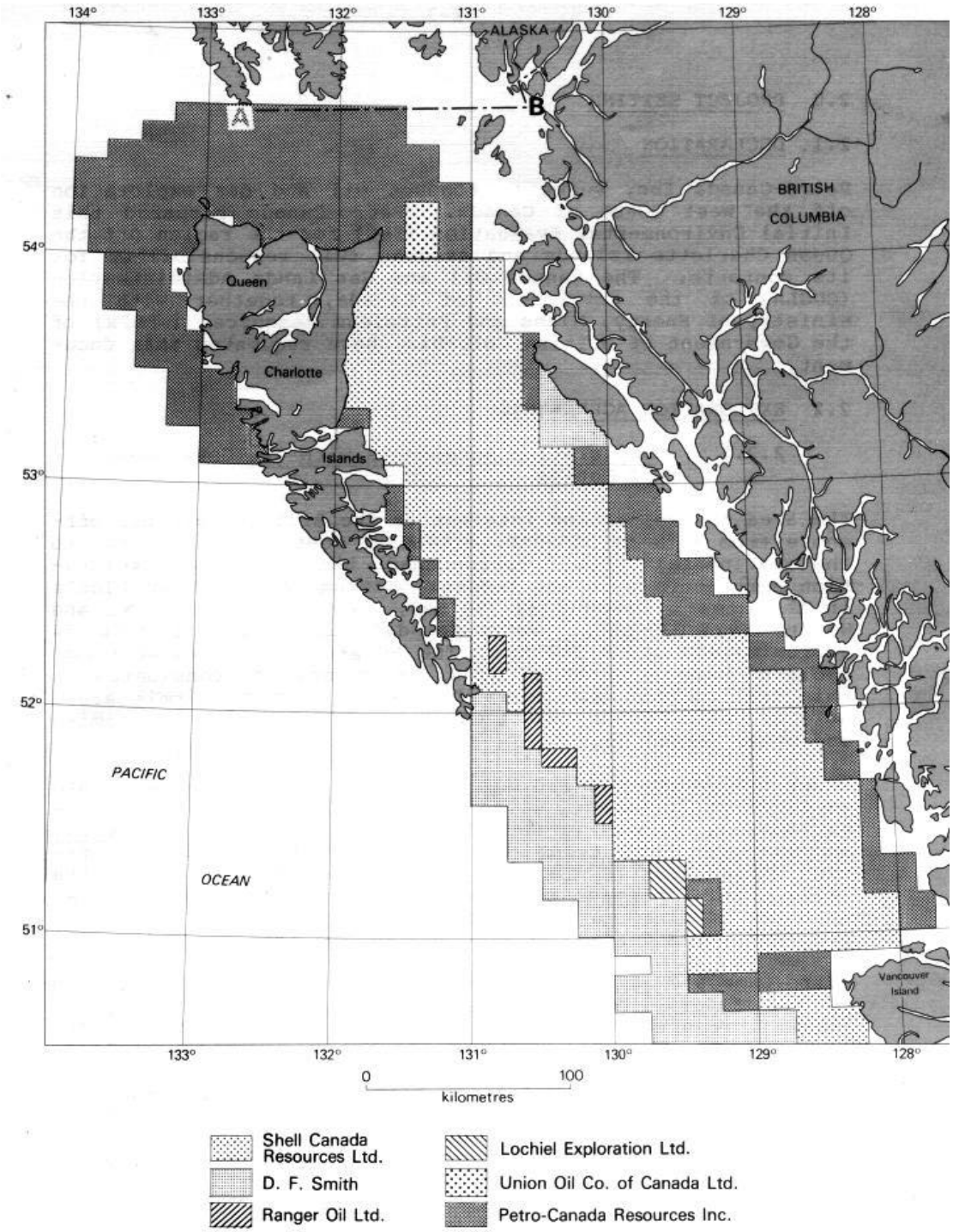
Source: LGL Environmental Research Associates 1999

A3 Agencies and Jurisdiction

Agency	Jurisdiction and Role	Acts and Regulation
Fisheries and Oceans	Protection of fish habitat, assessment of impacts and approval of activities and structures.	· Fisheries Act
Environment Canada	Environmental impact assessments, support for other regulators.	· Canadian Environmental Protection Act
Canadian Environmental Assessment Agency	Co-ordination of assessment processes at Federal level	· Canadian Environmental Protection Act · Canada-British Columbia Agreement for Environmental Assessment Cooperation
National Energy Board	Regulation of oil and gas activities that cross provincial boundaries; operation of facilities, construction, marketing	· NEB Act · Onshore Pipeline regulations · Pipeline Crossing regulations
Canada Coast Guard	Safety and environmental protection of navigable waters	· Canada Shipping Act · Oil Spill Response Regime
Natural Resources Canada. Energy Sector	Enhance economic and environment by fostering sustainable development of Canada's energy resources	
BC Ministry of Energy and Mines	Management of energy, mineral and petroleum resources to ensure environmental protection and worker; collects revenues	· Petroleum and Natural Gas Act · See also: http://www.em.gov.bc.ca/links/legislat.htm
BC Ministry of Environment, Lands and Parks	Management, protection and enhancement of the environment including provincial wildlife, water, and air resources, provincial parks, recreation areas and ecological reserves; the management and allocation of Crown land	· Environment Management Act
BC Environmental Assessment Office	Co-ordinates assessment of the impacts of major development proposals	· BC Environment Assessment Act · Canada-British Columbia Agreement for Environmental Assessment Cooperation

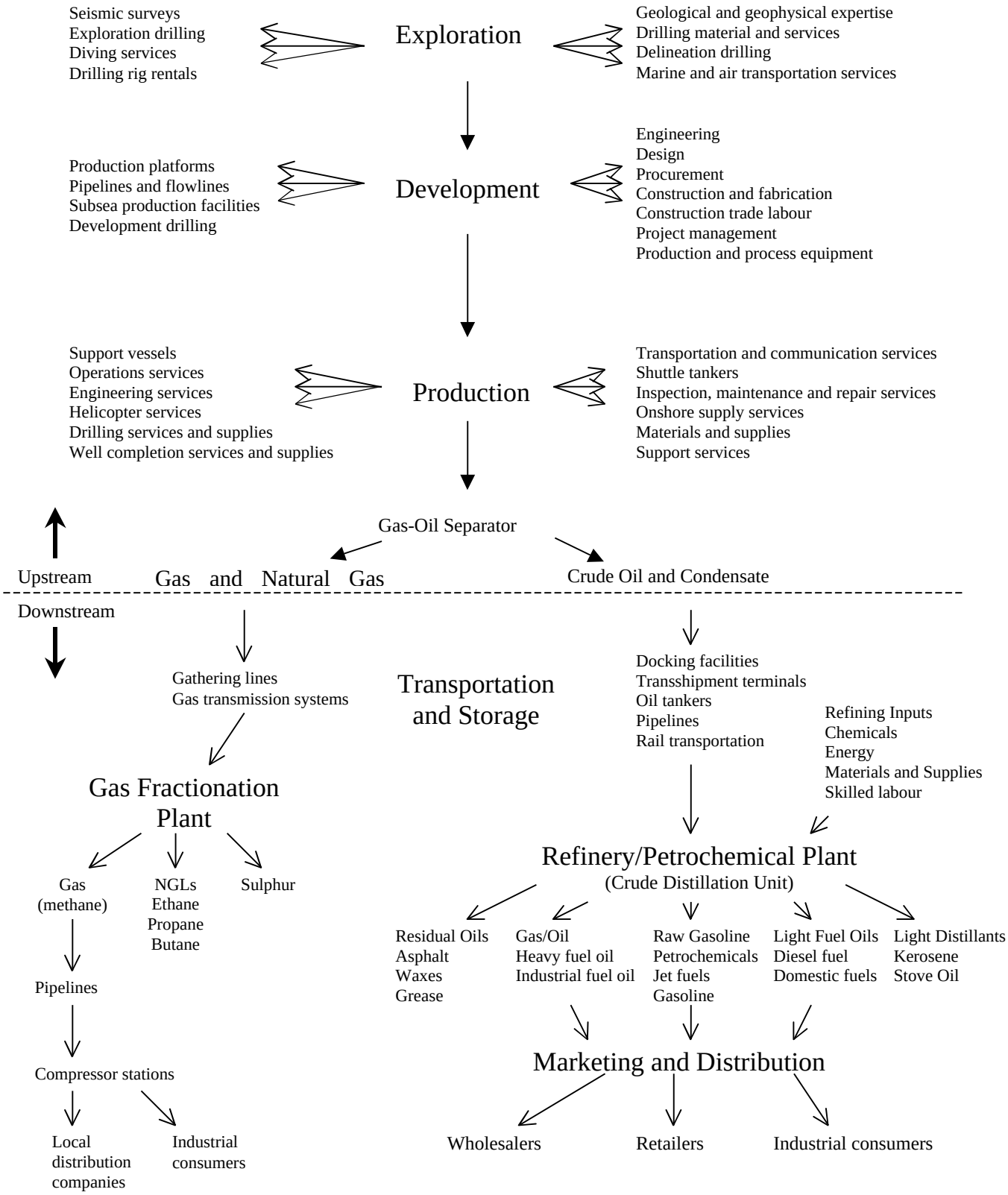
Agency	Jurisdiction and Role	Acts and Regulation
BC Utilities Commission	Regulates crude oil gathering lines and gas and electric utilities	
BC Northern Development Commission	Promote job creation, facilitate economic development and attract investment to northern BC	
BC Oil and Gas Commission	Regulates the crude oil, natural gas and pipeline activities in BC	· Oil and Gas Commission Act · Petroleum and Natural Gas Act · Pipeline Act
BC Fisheries	Build and sustain diverse and healthy native fish populations, management of fish, their habitats and the fisheries	· Fish Protection Act
BC Land Use Coordination Office	Facilitates land-use decisions, set strategic direction, co-ordinate work-plans and monitor and report on ministry programs	
BC Ministry of Employment and Investment	Job creation and economic development by promoting increased trade, investment and development	· Http://www.ei.gov.bc.ca/Links/legislat.htm
BC Ministry of Labour	Regulates and promotes safety, health, fairness, and equity in the workplace	
BC Parks	Contained with in the area is one national park, eight provincial parks and 13 ecological reserves	
Municipal governments and Regional authorities	Administer local by-laws, plans and regulations	
Canada-Nova Scotia Offshore Petroleum Board	Regulation of petroleum activities in NS offshore including worker safety, environmental protection and resource management	· Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act (federal and provincial)
Canada-Newfoundland Offshore Petroleum Board	Administers all petroleum activities in NF offshore	· Canada-Newfoundland Atlantic Accord Implementation Act

A4 Map of Offshore Leases



British Columbia offshore oil and gas leases. Note that the Shell leases have been farmed out to Chevron Canada Resources Limited. Figure taken from Petro-Canada Inc. 1983. Offshore Queen Charlotte Islands Initial Environmental Evaluation. Volume I.

***A5 Oil and Gas Value Chain (Source: Harnessing the Potential-Atlantic Canada's Oil and Gas Industry*, NOIA 1998)**



A6 Selected References

Adams,C.J. and Burnell,A.J. Conductor and riser design for fixed drilling platforms in the marine environment. *In*: The marine environment and oil facilities.

Oil well conductor and oil export riser design for North Sea fixed drilling and production platforms is reviewed from a structural engineering viewpoint. The primary purposes of the conductor pipe are outlined with an emphasis on the requirements for supporting internal casing strings and resisting external environmental loads. Corrosion protection of the oil export riser is highlighted as a critical design problem. Finally, the combined influence of conductors and risers on the main tower design is discussed. The oil export riser is concluded to be a more vulnerable portion of the oil flowline than conductors although the consequences of damage or deterioration of the oil export riser are slight compared to the effects of damage to the main oil well conductor.

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

Anonymous. 1999. Oil and gas in the environment: Executive summary. Science of the Total Environment **234(1-3)**:239-242

Our society and economy have become dependent on oil and gas. The UK uses oil and gas for more than two-thirds of its energy needs - to run its transport network, heat its homes, in industrial processes, and to produce over a quarter of its electricity. There has been a steady increase in consumption of petrol, diesel and aviation fuel since 1970 mostly for transportation, although consumption of fuel oil has fallen dramatically. This has largely been replaced in the industrial and domestic sectors by gas, the consumption of which has risen sharply since 1990. This report assesses how this dependence on oil and gas is affecting the environment, and looks at the impact of the increasing consumption of oil and gas on the environment. The need to regulate and manage these implacts has been recognised for many years. The report forms the Environment Agency's view on the general state of pollution of the environment in relation to oil and gas. It looks at how well existing regulations and controls are working in practice and what more needs to be done, both by the Agency itself and by others, to reduce pollution. After giving a background to the formation of oil and gas and the history of their exploitation, the report summarises who does what in regulation. It then takes a life-cycle approach to look at the pressures on the environment from the exploration, production, transportation, refining, storage, and the use of oil and gas, and finally the disposal of used oil and oily waste.

Bedborough, DR, Blackman, RAA and Law, RJ. 1987. A survey of inputs to the North Sea resulting from oil and gas developments. Environmental Effects of North Sea Oil and Gas Developments. Philosophical Transactions of the Royal Society of London, Series B **316B(1181)**:495-509

The annual input of petroleum hydrocarbons to the North Sea has recently been estimated to be between 100 and 170 kt and is derived from a variety of sources. At present, experience in the United Kingdom has shown that this input of fresh,

unweathered oil rapidly enters otherwise uncontaminated offshore sediments, producing strictly local effects around the point-source discharges. Of the 140 kt of materials other than oil discharged annually to the North Sea from oil and gas developments in the United Kingdom, 98-99% arise from drilling operations, but the vast majority of inputs from this source are biologically inert or derivatives of natural products. The largely uncontaminated offshore North Sea waters and sediments remain little affected by offshore oil and gas developments, but if these activities enter already contaminated estuarine and coastal waters, the contamination and effects from this source will be harder to distinguish.

Birtwell, IK, Fink, R, Brand, D, Alexander, R and McAllister, CD. 1999. Survival of pink salmon(Oncorynchus gorbuscha) fry to adulthood following a 10-day exposure to the aromatic hydrocarbon water-soluble fraction of crude oil and release to the Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences. **56(11)**:2087-2098

Saltwater-acclimated, coded-wire tagged, and adipose fin clipped pink salmon (Oncorynchus gorbuscha) fry were exposed for 10 days to seawater (control) or 25-54 mu g times l super(-1) (low dose) or 178-349 mu g times L super(-1) (high dose) of the water-soluble fraction (WSF) of North Slope crude oil. The WSF was composed primarily of monaromatics and was acutely lethal to the fry: 96-h LC sub(50) ranged from 1 to 2.8 mg times L super(-1). After exposure the fry (30 000 per treatment) were released into the Pacific Ocean to complete their life cycle. The experiment was replicated in 1990, 1991, and 1992. There was no consistent significant dose-dependent effect of the 10-day exposure to the crude oil WSF on growth of the pink salmon prior to their release. Adult pink salmon from this experiment were captured in fisheries and also recovered from their natal Quinsam River, British Columbia. Pink salmon from each treatment group were recovered in similar numbers. Exposure of populations of fry to the WSF of crude oil and release to the Pacific Ocean did not result in a detectable effect on their survival to maturity. Fry from all treatment groups incurred typically high mortality following release, and there were no discerible effects on survival that were attributable to exposure to the WSF of crude oil.

Blondina, G. J., Singer, M. M., Lee, I., Ouano, M. T., Hodgins, M., Tjeerdema, R. S. and Sowby, M. L. 1999. Influence of salinity on petroleum accommodation by dispersants. Spill Science & Technology Bulletin. **5(2)**:127. http://elsevier.com

The effect of receiving water salinity on the effectiveness of two oil dispersants, Corexits(r) 9527 and 9500, was investigated using a recently implemented modified version of the Swirling Flask efficacy test. The dispersants were tested with ten different oils, representing a wide range of physical-chemical properties. Test salinities ranged from 0 to 35 ppt, with temperature held constant at 15 deg. C. Results showed Corexit 9500 to be generally more effective on most of the dispersible oils at most salinities, but performance of both products was significantly affected by salinity. Both dispersants performed best at salinities above 25 ppt, with Corexit 9500 maintaining its

effectiveness over a fairly wide range of salinities. Correlations between dispersant effectiveness and various oil physical/chemical properties were highly variable.

Booman, C, Dalen, J, Leivestad, H, Levsen, A, Van der Meeren, T and Toklum, K. 1996. The physiological effects of seismic explorations on fish eggs, larvae and fry. Fisken og Havet. Havforskningsinstituttet, Bergen (Norway). No. 3 83 pp

Fish in their early life stages as eggs, larvae, and fry are in the most exposed positions for harmful impacts from seismic explorations. They are physiologically vulnerable, and unlike to larger fish, they are not able to move away from the volumes around the air guns. The background for this project was that previously conducted experiments up to 1990 did not directly elucidate particular aspects of actual Norwegian problems. The fish species used were not fully representative of Norwegian waters, and all actual sizes of air guns were not applied during previous Norwegian experiments. Additionally one should apply histological and pathological competance to verify different internal injuries at both instantaneous mortality of larvae and fry and at sublethal conditions. The main goal of this study was thus to provide new and supplementary knowledge to describe and evaluate harmful effects on eggs, larvae, and fry from seismic surveys applying air guns in order to contribute to fishery management.

Boudreau, PR, Gordon, DC, Harding, GC, Loder, JW, Black, J, Bowen, WD, Campana, S, Cranford, PJ, Drinkwater, KF, Eeckhaute, L Van, Gavaris, S, Hannah, CG and Harrison, G. 1999. The possible environmental impacts of petroleum exploration activities on the Georges Bank ecosystem. Department of Fisheries and Oceans, Dartmouth, NS Marit. Reg. Canadian technical report of fisheries and aquatic sciences. No. 2259, 112 pp

A Department of Fisheries and Oceans Regional Advisory Process was carried out to generate a peer-reviewed summary of the Georges Bank ecosystem and potential impacts from petroleum exploratory activities. The process included input from Canada and USA government scientists, external reviewers and representatives from fisher groups and the petroleum industry. The review resulted in the following conclusions: Georges Bank is an important bank that has a number of features, which, in combination with its size makes it unique. Routine exploratory seismic activity might have a significant but temporary impact on adult fish behaviour and movement. This might affect fish catch rates and spawning behaviour. Routine operational exploratory drilling activity is likely to have only localized impacts on the ecosystem components reviewed. The actual impacts will be dependent on the location, timing of the activities, and the properties of discharges. There does exist a small probability that these impacts will have population and ecosystem level impacts. Exploration drilling would lead to a temporary loss of access to some portion of the fishing grounds, although the area lost would be relatively small. Seismic activity would lead to temporary space conflicts with fishing activities that would depend on timing, location and the gear types involved. There is a low probability of a large release of petroleum product from a well blowout. If this were to occur, it might have population and ecosystem level impacts. Routine

exploratory seismic activity could have a localized impact on eggs and larvae depending on the time of year and location.

Briggs, KT, Gershwin, ME and Anderson, DW. 1997. Consequences of petrochemical ingestion and stress on the immune system of seabirds. International Counc. for the Exploration of the Sea, Copenhagen (Denmark). Seabirds in the Marine Environment. Proceedings of an ICES International Symposium held in Glasgow, Scotland, 22-24 November 1996. ICES J. Mar. Sci. **54(4)**:718-725

The immune system is a target of toxicants and there is increasing awareness of the role of environmental pollutants in altering immune function. Immune suppression may constitute a previously unappreciated source of both acute and chronic impacts on seabirds affected by spilled oil. Thus, it is important to determine (1) if immunosuppression occurs, (2) its importance compared to other mechanisms of impact, (3) its timing and chronicity relative to oil ingestion and post-spill cleaning efforts, and (4) if something can, and should be, done to mitigate its effects. Among oiled birds, leukocyte numbers (especially lymphocytes) are depressed in the circulation and the major lymphoid organs (spleen and bursa of Fabricius). At the same time, bone marrow hypercellularity, with and emphasis on erythropoiesis, suggests an adaptive shift from white cell to red cell production in response to haemolytic anaemia. Secondary fungal and bacterial infections, common among seabirds in rehabilitation centres, emphasize the immunosuppressive qualities of petrochemicals. Furthermore, inflammation of the gastrointestinal tract following oil ingestion leads to malabsorption of nutrients (which is immunosuppressive), damage to mucosal immune defences, and impairment of responses to certain antigens, such as those of foods. Unfortunately, direct challenge by viral or bacterial pathogens has been incorporated into very few relevant, laboratory studies: compared with experimental controls, domestic birds fed petroleum distillates and/or oil-emulsifying agents suffer greater mortality, and have depressed ability to kill or phagocytize bacterial pathogens. Cell-mediated immune mechanisms are more sensitive to the toxic effects of petrochemical ingestion than are mechanisms related to antibody production. Petrochemical ingestion produces abnormal concentration or accelerated metabolism of adrenal corticosteroids. The same is true for birds subjected to handling stress, such as occurs during experimentation with wild birds, and during cleaning of oil-soaked birds. Corticosteroid hormones affect the immune system in many ways, including changes in numbers, and depression of function among lymphocytes. Results of the few recent studies of birds released from cleaning facilities are consistent with the notion of chronic, toxic, or immune system problems. These birds suffer higher than expected mortality rates, disappear from expected breeding and dispersal areas, and generally fail to breed for one or more years. Better long-term success might be obtained with improved assessment of immune function during captivity, and with the use of non-specific potentiators of immune function.

British Columbia Ministry of the Environment (BCME). 1983. A Preliminary Environmental Assessment of he Offshore Hydrocarbon Exploration and Development.

Canada Oil and Gas Lands Administration (COGLA) and British Columbia Ministry of Energy, Mines and Petroleum Resources (BCMEMPR). 1984. Technical Evaluation of the IEEs for Offshore Petroleum Exploration North of Vancouver Island.

Canada Oil and Gas Lands Administration (COGLA) and British Columbia Ministry of Energy, Mines and Petroleum Resources (BCMEMPR). 1988. Status of the Federal-Provincial Government Response to the West Coast Offshore Exploration Environmental Assessment Panel Report.

Canadian Association of Petroleum Producers Foundation Paper 1998. http://www.capp.ca/

Carls, M. G., Rice, S. D. and Hose, J. E. 1999. Sensitivity of fish embryos to weathered crude oil: Part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval Pacific herring (Clupea pallasi). Environmental Toxicology and Chemistry. **18(3)**:481

Pacific herring eggs were exposed for 16 d to weathered Alaska North Slope crude oil. Exposure to an initial aqueous concentration of 0.7 parts per billion (ppb) polynuclear aromatic hydrocarbons (PAHs) caused malformations, genetic damage, mortality, and decreased size and inhibited swimming. Total aqueous PAH concentrations as low as 0.4 ppb caused sublethal responses such as yolk sac edema and immaturity consistent with premature hatching. Responses to less weathered oil, which had relatively lower proportions of high molecular weight PAH, generally paralleled those of more weathered oil, but lowest observed effective concentrations (LOECs) were higher (9.1 ppb), demonstrating the importance of composition. The LOEC for more weathered oil (0.4 ppb) was similar to that observed in pink salmon (1.0 ppb), a species with a very different development rate; by inference, other species may be similarly sensitive to weathered oil. Our methods simulated conditions observed in Prince William Sound (PWS) following the Exxon Valdez oil (EVO) spill. Biological effects were identical to those observed in embryo larval herring from PWS in 1989 and support the conclusion that EVO caused significant damage to herring in PWS. Previous demonstration by our laboratory that most malformed or precocious larvae die corroborates the decreased larval production measured after the spill.

Caswell, MF. 1991. Economic effects of oil and gas development on marine aquaculture leases. Study 17. California Univ., Santa Barbara (USA). 60 pp

There are three primary mariculture products grown in California waters: oysters, mussels, and abalone. In total, the California mariculture industry earns revenues of about $6.5 million. Water quality degradation was the primary concern of most growers. Coliform bacteria and pesticide residues are currently threatening several shallow-water

sites. Lease holders (and potential lease holders) for deep-water sites state that coliform bacteria from municipal sewer outfalls and offshore oil and gas drilling effluents are the greatest dangers to their profitability. The Southern California Educational Initiative is an attempt to determine whether such concerns are warranted. A simple model of economic externalities was described to highlight the scientific data one must gather so as to choose the optimal production levels for both energy and mariculture resources. That information is necessary to assess the economic consequences to the California mariculture industry of chronic exposure to oil and gas development. The co-development model shows that the marginal (incremental) effects of oil production on mariculture costs needs to be assessed. The model also shows that if the effects are moderated by distance from the point of discharge, such changes must be estimated in order to determine optimal lease boundaries. The report concludes that interdisciplinary cooperation is essential for designing a co-development plan that maximizes the social welfare to be gained from developing multiple coastal resources.

Chevron Canada Resources Limited. 1982. Initial Environmental Evaluation for Renewed Petroleum Exploration in Hecate Strait and Queen Charlotte Sound. Volumes 1 and 2.

Congar, R. 1983. Economic assessment of marine oil pollution impact on living organisms. Institut Scientifique et Technique des Peches Maritimes, Nantes (France). Oil Pollution Impact On Marine Flora And Fauna. A Collective Report. Impact Des Hydrocarbures Sur La Flore Et La Faune Marines. Rapport Collectif. pp. 183-212

The social cost of pollution is studied from the standpoint of revenue lost from production which should have been a benefit for the human community in the absence of any pollution; for example losses in tourism, fisheries, sand exploitation. The Amoco Cadiz oil spill is used as an example. Losses were important in fish and crustacean fisheries. Fishing boats and gears were also damaged. Losses in fisheries and mollusc culture are financially evaluated. The Amoco Cadiz oil pollution effects are also evaluated for non-commercial marine resources.

Corrosion in risers. Offshore Res. Focus. No. 8, 2

The effects of a failure in an oil riser on an offshore production platform are obviously serious in terms of finance, safety and pollution. The difficulty of predicting corrosion rates in hot riser pipes and flow lines has been caused by a scarcity of relevant data, but a project funded by the Department of Energy aims to provide the necessary data. A consortium of the National Corrosion Service, the National Maritime Institute and the National Physical Laboratory is carrying out a test programme on the corrosion of hot steel in seawater and saline mud; and the steel and oil industries are advising on the content of the programme. Tests are being made at ambient temperatures and under the severe temperature and heat flux conditions met in practice. The corrosion problems of offshore steel structures are intensified in the risers conveying hot oil, even when protective coatings and cathodic protection are in use. Data are sparse: a corrosion rate

in seawater of 7.5 mm in 400 days for a pipe carrying oil at 90 C has been reported. Particular attention is being paid to: (1) corrosion rates of typical riser and pipeline structural materials under metal-to-sea and metal-to-mud heat transfer; (2) the level of cathodic protection potential necessary to confer immunity to corrosion under heat transfer conditions; (3) the long-term behaviour of sacrificial anodes.

Cowles, CJ, Hansen, DJ and Hubbard, JD. 1981. Types of potential effects of offshore oil and gas development on marine mammals and endangered species of the northern Bering Sea and Arctic Ocean. Bureau of Land Management, Anchorage, AK (USA). Alaska Outer Cont. Shelf Off. Tech. Pap. Bur. Land Manage. No. 9, BLM, Anchorage, AK (USA). 32 pp

The report summarizes information on the types of potential effects on marine mammals, endangered species, and rare plants which may be associated with oil and gas lease sales pending for the northern Bering Sea and arctic regions. The discussion does not imply that any specific level of impact will be sustained but rather identifies the various potential effects assiciated with offshore exploration, development, and production of petroleum hydrocarbon resources in the Alaska arctic regions.

Cranford, PJ, Gordon, DC Jr, Hannah, CG, Loder, JW, Milligan, TG and Muschenheim, DK. 1999. Modelling potential effects of drilling wastes on George's Bank scallop stocks. Journal of Shellfish Research **18(1)**:312

Moratoria on oil and gas activities on Georges Bank are currently in place until 2000 (Canada) and 2012 (USA). If not extended, exploration drilling could take place with the attendant risks to the marine ecosystem and aquatic resources. A numerical benthic boundary layer transport model (bblt) was developed to provide estimates of the suspension, drift, dispersion and concentration of water-based drilling mud which could be released from a hypothetical 92-day exploration well at different sites on Georges Bank. Simulations predict that highest near-bottom concentrations of drilling mud would occur in the relatively deep Side region (>100 m) as a result of relatively low suspension, dispersion and drift. Lowest concentrations would occur in the central Mixed region (<65 m) because of high dispersion, while intermediate concentrations would occur in the Frontal region. Laboratory experiments show that adult scallops are highly sensitive to drilling mud, and the near-bottom concentration time series from bblt simulations provide a basis for estimating impacts. The region of greatest potential impact on scallop growth is the Side region where mud concentrations from the hypothetical release scenario are predicted to prevent scallop growth for 2-40 days depending upon the settling velocity used and area over which results are averaged. Scallop stocks in this region are relatively small but dense aggregations are found in some areas. Growth losses in the Frontal region, which has the densest scallop stocks, are predicted to be more localized and confined to a range of 0-15 days. Predicted growth loss in the central Mixed region is predicted to be negligible (<2 days).

Cranford, PJ, Gordon, DC Jr, Lee, K, Armsworthy, SL and Tremblay, G-H. 1999. Chronic toxicity and physical disturbance effects of water- and oil-based drilling

fluids and some major constituents on adult sea scallops (Placopecten magellanicus). Marine environmental research. London. **48(3)**:225-256

Adult sea scallops, Placopecten magellanicus, were exposed in the laboratory under environmentally representative conditions to different types and concentrations of used operational drilling fluids and their major constituents. Threshold waste concentrations causing reductions in somatic and/or reproductive tissue growth are: greater than 10 mg 1 super(-1) for used water-based mud (WBM); 2 mg 1 super(-1) for bentonite; and less than 0.5 mg 1 super(-1) for barite and used oil-based mud (OBM). Chronic exposure to OBM caused high mortalities at concentrations as low as 1.0 mg 1 super(-1). Non-nutritious particles in the food supply (all wastes) and chemical toxicity (OBM and perhaps barite) affected the growth rate and survival of sea scallops by altering physiological state (scope for growth) and nutritional condition (O:N ratio). The value of scope for growth (SFG) calculations for assessing the relative chronic toxicity of the drilling wastes was demonstrated by the close relation observed between SFG and actual growth measurements. These results show that chronic intermittent exposure of sea scallops to dilute concentrations of operational drilling wastes, characterized by acute lethal tests as practically non-toxic, can affect growth, reproductive success and survival.

Daan, R and Mulder, M. 1996 Environmental effects of offshore drilling activities. Annual Report Netherlands Institute for Sea Research. pp. 62-63.

There has been an extensive use of oil based drilling muds (OBM) during drilling activities in the North Sea in the 80's and early 90's. Drill cuttings from wells drilled with OBM were discharged on the seabed and considerable amounts of OBM base oil adhering to drill cuttings have contaminated the seabed around well sites. Field studies on the environmental effects of these discharges have been carried out on the Dutch Continental Shelf (DCS) since 1985. The majority of these studies were initiated by RWS (North Sea Directorate) and carried out by NIOZ in cooperation with MT-TNO Den Helder. Initially the attention focused on short-term effects. However, from 1993, when a ban was introduced on the offshore discharges of oil contaminated drill cuttings, the research has shifted to the long-term effects of the former discharges. Three platforms, in the northern deposition area, the southern erosion area and the transition zone, respectively, received particular attention. After repeated field surveys during the first years after drilling had ceased at these locations, extensive long-term surveys were carried out at each of them, to assess the intensity and spatial extent of pollution and associated biological effects 6 to 8 years after drilling. Additionally, in 1994 and 1995, a compendious sampling programme was executed covering 12 well sites in different areas of the DCS and including actual production platforms but also a few abandoned well sites. At each of these locations one or more wells had been drilled with OBM 7 to 13 years ago. Discharge loads were variable and ranged from 10 to 400 tonnes of base oil per location. Each survey comprised benthos sampling of a few stations within 2000 m from the discharge site. In order to describe the long-term impact of the former OBM cutting discharges on the DCS, information is available now from 15 well sites with a wide variation in drilling history.

Daan, R and Mulder, M. 1996. On the short-term and long-term impact of drilling activities in the Dutch sector of the North Sea. International Counc. for the Exploration of the Sea, Copenhagen (Denmark). Changes in the North Sea Ecosystem and Their Causes: Aarhus 1975 Revisited. Proceedings of an ICES International Symposium held in Aarhus, Denmark. ICES J. Mar. Sci.Dec. **53(6)**:1036-1044

A research programme on the effects of drill-cutting discharges on the benthic system around platforms on the Dutch continental shelf has been running since 1985, with emphasis on locations where oil-based drilling muds (OBM) have been used and discharged. A few locations where only water-based muds (WBM) have been used were also investigated. At OBM locations, elevated total hydocarbon concentrations in the sediment occurred up to 750-1000 m from well sites during the first year after discharges had stopped. Concentrations tended to decrease to natural background levels during the following years at distances greater than or equal to 500 m from the platform, but remained far higher than background levels even after 8 yr within a few hundred metres. One year after drilling, biological effects of OBM discharges were detectable up to greater than or equal to 1000 m by reduced abundances of a few very sensitive species (particularly Echinocardium cordatum and Montacuta ferruginosa). Closer to well sites, increasing numbers of species experienced adverse effects. In the longer term, the macrofauna seemed to recover at distances greater than or equal to 500 m, but within that range the macrofauna was still affected after 8 yr. Possible effects of WBM discharges were investigated at a few single-well sites during surveys carried out within 2 mo 1 yr after discharges were terminated. Adverse effects on the benthic community were not observed, even within 25 m of a discharge site.

Dalen, J. Impact of seismic impulsive energy on marine organisms.12 pp

Marine geophysical surveying is used to identify geological structures and thus forms the basis for exploration and exploitation of hydrocarbon resources. Low frequency sound energy is transmitted from a special source that penetrates the sediments and parts of this energy are scattered back from sediment layer boundaries. By properly receiving and processing of the backscattered sound energy, cross section maps of the geological structure patterns can be made. When considering impacts of seismic explosive pulses on marine organisms in general terms, we should rather consider all kinds of marine seismic prospecting. This, however, will be beyond the scope of this presentation where we will concentrate on offshore seismic prospecting for oil and gas reservoirs.

Davies, J.M. 1981. Environmental effects of North Sea oil operations. Marine Pollution Bulletin. **12(12)**:412-416.

To appreciate the impact of large-scale industrial operations on the marine environment requires a range of scientific studies which ideally should include physical, chemical and biological surveys of the various environmental compartments likely to be contaminated, linked with experiments designed to detect and quantify effects. More finely focused studies can then provide en evaluation of the impact. In relation to North

Sea oil activities, this type of approach suggests that at present significant offshore contamination is found only in the sediments close to platforms using oil-based drilling muds.

Dietrich, J.R. 1995. Petroleum resource potential of the Queen Charlotte Basin and environs, west coast Canada. Bull. Can. Pet. Geol. **43(1)**:20-34.

The Queen Charlotte Basin region of the west coast of Canada has significant petroleum potential. Sedimentary basins within the region contain abundant reservoir strata, oil and gas source rocks, diverse trap types and numerous oil and gas shows. A quantitative assessment of the petroleum potential in the Queen Charlotte Basin region provides estimates of total recoverable resources of 414 million m^3 (2.6 billion barrels) of oil and 565 billion m^3 (20 Tcf) of gas, at median values. The resource estimates are based on evaluations of three conceptual petroleum plays involving Cretaceous and Neogene sandstone and conglomerate reservoirs and Jurassic and/or Tertiary source rocks. The most prospective plays occur in Neogene strata within the Queen Charlotte Basin, beneath eastern Graham Island and in the offshore shelf areas of Dixon Entrance, Hecate Strait and Queen Charlotte Sound. While the assessment study provides a favourable geological basis for future petroleum exploration in the Queen Charlotte Basin region, the complex geology and anticipated risks associated with the petroleum plays suggest considerable amounts of new seismic surveying and exploratory drilling may be required to adequately evaluate the region's oil and gas potential.

DiFrancesco, R. J. 1998. The Crown, territorial jurisdiction, and aboriginal title: issues surrounding the management of oil and gas lands in the Northwest Territories. Energy Studies Review. **8(3)**:232

DiFrancesco, R. J. and Anderson, W. P. 1999. Developing Canada's arctic oil reserves: an assessment of the interregional economic impacts. **31(3)**:459. http://www.pion.co.uk/ep/

In this paper we assess the economic impacts of two scenarios of offshore oil development in Canada's Arctic: one based on pipeline transportation and the other based on tanker transportation. A dynamic multiregional input – output model is specified in order to take account of substantial regional spillover effects and capacity expansion effects within the Northwest Territories. The results indicate that in both scenarios a large share of the economic benefits accrue to other regions, but that the pipeline scenario yields greater benefits for the Northwest Territories. Differences between the two scenario results are explained in terms of the spatial and sectoral patterns of input requirements and differences in capacity expansion effects.

Doubleday, NC. 1996. "Commons" concerns in search of uncommon solutions: Arctic contaminants, catalyst of change? Science of the Total Environment. **186(1-2)**:169-179

The Arctic Ocean is of increasing interest internationally, as a transportation route, as a resource pool, and as a hotbed of social and governmental change driven by indigenous claims. Unfortunately it is also receiving significant attention internationally because of its role as a possible sink for global transport of contaminants produced by industry and used in a wide range of agricultural and industrial applications. Regional concerns about contamination include identification of sources of production within and beyond the Arctic Region, transport and deposition of a wide range of contaminants by the atmospheric, oceanic and riverine delivery systems, and the expression of ecological effects. Transcending all of these scientific aspects of this issue are the strongly held concerns at the local level where what is at stake is the future of a sustainable way of life with ancient roots based on harvesting of renewable resources. The North Atlantic Region has already seen the consequences of many of the development pressures which will be brought to bear on the Arctic, such as off-shore oil production. Increased understanding of environmental as well as economic consequences of irreversible development choices is bound to be beneficial to the decision-making process. Finally as the Arctic contaminants issue has shown, the framework used for making development choices everywhere must be broadened to consider the long term global consequences of those decisions.

Ellis, MS, Wilson-Ormond, EA and Powell, EN. 1996. Effects of gas-producing platforms on continental shelf macroepifauna in the northwestern Gulf of Mexico: Abundance and size structure. Canadian Journal of Fisheries and Aquatic Sciences **53(11)**:2589-2605

Macroepifaunal populations near 3 active gas-producing platforms were studied as part of the Gulf of Mexico Offshore Operations Monitoring Experiment (GOOMEX) using a near-field (50-100 m), far-field (3 km) collection strategy. When differences in catch per unit effort (CPUE) existed, they were species and site specific. Size effects were not solely due to sexual dimorphism. Differences in size and abundance did not co-vary. General responses to the presence of platform structure or other characteristics common to gas-producing platforms were not observed. CPUE was site (platform) specific, indicating that epifauna responded to the unique physical and chemical characteristics of each platform. The frequency of significant near-field/far-field differences declined with increasing depth as did the frequency of significant seasonal and time-of-collection differences in size and CPUE, suggesting that platforms affect adjacent community structure more strongly in shallow water and that seasonality and behavior patterns may be more important promoters of this effect. Significant differences occurred no less frequently in the most mobile species (penaeid shrimp) than in the less mobile starfish and scallops. Discrete populations of mobile epifauna maintain their coherence for significant periods, which permits differential effects produced by nearness to platforms to be expressed in some of the most mobile invertebrates on the shelf.

Engaas, A, Loekkeborg, S, Ona, E and Soldal, AV. 1993. Effects of seismic shooting on catch and catch-availability of cod and haddock. Fisken og Havet. No. 9. 117 pp

In May 1992 an experiment was carried out on North Cape Bank in the Barents Sea in order to answer the following 3 questions: 1) Does seismic shooting with air guns affect catch and catch-availability of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus)? 2) How far away from the seismic shooting area can possible effects be demonstrated? 3) How long after the conclusion of seismic shooting can possible effects be demonstrated? This was done by means of fishing trials with trawl and longline and acoustic mapping of the fish distribution before, during and after the seismic shooting. The acoustic mapping and catching trials with trawl and longline on North Cape Bank show that the seismic shooting with air guns affects the fish distribution and catch rates for cod and haddock, not only locally within the area where the shooting is carried out, but also in significant surrounding areas. The catches by trawl and longline consisted principally of cod and haddock, with cod as the dominant species. The trawl catch rates both for cod and haddock declined over the entire investigation area, even to the border, 18 nm from the shooting area. On average for the whole area, the catch rate was halved when the shooting began. The reduction was greatest in the center of the seismic shooting area. Here the average catch for both species was reduced by approximately equals 70% during the shooting. The reduction in the trawl catches generally agreed with the acoustic observations, which showed a reduction of approximately equals 45% in the total quality of cod and haddock within the investigation area. The reduction in acoustic quantity was also greatest in the central area.

Futsaeter, G. 1994. Environmental policy and regulation for oil exploration and shipping activities in the Barents Sea. Proceedings Of ENS (Environment North Seas) '93 Conference Held In Stavanger, 24-27 August 1993. Marine Pollution Bulletin **29(6-12)**:348-353

The Barents Sea has one of the highest levels of biological production of all the world's oceans, and holds some of the largest fish stocks and concentrations of seabirds. Environmental conditions in the area make it particularly vulnerable to damage from human activities. Given the vulnerability of this ecosystem to the effects of human activity, and the fact that physical factors (e.g. reduced visibility, ice) increase risks due to oil exploitation and shipping activities, environmental authorities will work towards more stringent discharge limits and higher standards for emergency preparedness for both oil exploitation and shipping in the Barents Sea. The Norwegian Pollution Control Authority gives priority to preventive measures that can lower the probability of accidents and particular emphasis will be given to conditions attached to production licenses and controls on activities in areas that have not yet been opened for petroleum activities. Within the Arctic Environmental Protection Strategy (the Rovaniemi-process), Norway has proposed that efforts should be made to improve the protection of Arctic marine areas, and further that a working group including representatives of all the Arctic countries should assess various legal instruments and possible measures, and make recommendations for action. Currently, no special international requirements apply to ships sailing in ice-infested waters, and the recommendations from the working group will therefore be of great importance in protecting the area from damage from shipping.

Garamone, MD 1999. Stopping oil spills. Environmental Protection **10(6)**:45 http://www.eponline.com

Geraci, J.R. and St. Aubin,D.J. 1980. Offshore petroleum resource development and marine mammals: a review and research recommendations. Mar. Fish. Rev. **42(11)**:1-12

The development of offshore oil and gas reserves presents a number of potential threats to marine mammals. Seismic surveys employing various high explosives can be lethal at close range. Noise is associated with all phases of petroleum exploration and production. The physical, physiological, and behavioral effects of noise disturbance on marine mammals are poorly understood and need to be investigated. Exposure to spilled oil has been implicated as the cause of death of pinnipeds and cetaceans, however much of the evidence has been inconclusive. Marine mammals are unlikely to ingest sufficient quantities of oil to cause acute toxicity. However, the longterm effects of accumulation of petroleum fractions through the food chain are unknown. The ability of marine mammals to detect and avoid oil slicks is critical to any assessment of the potential impact of oil, and yet such information is clearly lacking. This review summarizes field observations and experimental studies of the effects of oil and oil exploration on marine mammals, identifies gaps in knowledge and establishes priorities for future research.

Gnezdova, TV and Kravchenko, AN. 1997. Aspects of environmental safety in the processes of the development of oil/gas fields offshore Sakhalin. Isope. **1**:38-41

The present stage of shelf development is characterized by the increase of involvement of its resources in economic use, by expansion of areas of oil and gas production and offshore geological exploration, by strengthening of impact of industrial activity onto the environment. The severe climate conditions and some other factors increase the probability of pollution of offshore environment and distributions of polluting substances to the regions, favorable for reproduction and a fishing of valuable biological objects. From the point of view of ecological safety by development of offshore oil and gas fields it is possible to mark out the following aspects: - Possibility of coexistence of fishing and oil and gas industries; - The ability of offshore hydrotechnical structured and facilities to resist the severe weather conditions; - Technical and financial possibilities of the Operator to ensure the effective implementation of works on elimination of accidental spills of oil and other polluting substances. The establishment of complex operative information of control during the solution of problems of observation over a state of environment in areas of development of Sakhalin offshore fields will enable to create a new system of ecological monitoring, which would allow: - to constantly trace the data on a change of quality of environmental components; - to create the ecological data bank within a short period of time; - to make various kinds of forecasts with a high degree of reliability; - quickly to respond in case of appearance of negative changes of environment or abnormal parameters of nature impacts.

Heintz, R. A., Short, J. W. and Rice, S. D. 1999. Sensitivity of fish embryos to weathered crude oil: Part II. Increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil. Environmental Toxicology and Chemistry. **18(3)**:494

We incubated pink salmon embryos under three exposure conditions, direct contact with oil-coated gravel, effluent from oil-coated gravel, and direct contact with gravel coated with very weathered oil (VWO). Embryo mortalities and polynuclear aromatic hydrocarbon (PAH) accumulation in embryo tissues during the direct-contact and effluent exposure experiments were not significantly different, indicating that PAH accumulation was mediated by aqueous transport. Mortality rate of embryos exposed initially to a total PAH concentration (TPAH) of 1.0 ppb were significantly higher than controls when the PAH were derived from VWO. The same aqueous TPAH concentration failed to increase mortality rates when the PAH were derived from less weathered oil, indicating that toxicity of effluents from the VWO was primarily associated with the larger PAH. We conclude that water quality standards for TPAH above 1.0 ppb may fail to protect fish embryos. Further, pink salmon embryos incubating in Prince William Sound after the Exxon Valdez oil spill may have accumulated lethal concentrations of PAH from interstitial water that was contaminated when it percolated through oil reservoirs located upstream from salmon redds.

Henriquez, LR. 1994. Risk assessment of offshore oil and gas activities in the Netherlands Proceedings Of ENS (Environment North Seas) '93 Conference Held In Stavanger, 24-27 August 1993. Marine Pollution Bulletin **29(6-12)**:317-322

Offshore oil and gas activities may lead to a conflict between the protection of the marine environment and health and safety aspects. Priority given to the protection of the marine environment may have an impact on the health or safety of the people working offshore and/or the integrity of the offshore installation. Previous health and safety protection measures are now known to create large-scale effects on the environment, e.g. the application of polychlorinated biphenyls as a cooling medium in transformers and the application of the ozone-depleting halons for efficient fire protection. Risk assessment, taking all health and safety aspects into account, may be the primary mechanism to justify operational procedures agreed by the national authorities as well as by the Exploration and Production industry. Risk assessment of health and safety aspects uses several models which are applied when designing new offshore installations. Several models, which have been developed in the last couple of years, are now available for the assessment of the environmental risk. This paper considers the need for the application of risk assessment with respect to all aspects, health, safety and environment, in order to determine a balanced set of priorities and protection measures.

Hill, AE, Seyfrit, CL and Danner, MJE. 1998. Oil development and social change in the Shetland Islands 1971-1991. Impact Assess. Proj. Apprais. **16(1)**:15-25

The Shetland Islands made considerable efforts to anticipate the effects of oil exploration on their culture. They aimed to preserve their local industries of agriculture,

fishing, and knitwear. Although the policies were not entirely successful, the local culture and economy have been preserved. From 1971-1991 total fishing industry employment declined by 24 percent and was not offset by a rise in ancillary employment.

Hiney, J. 1998. There's oil down there ...way down there. Texas Shores. **30(4)**:3-25

As traditional oil reservoirs on land and offshore begin to play out, oil producers are sinking to new depths to find reserves for future generations. The current world record is about 7,600 feet under the Gulf of Mexico. Recently discovered deepwater oil reserves in several places around the world offer the best hope for continued oil production outside of the Middle East. The well drilled in 7,600 feet of water by Shell was an exploratory well. Some producers already have pumping wells in 5,000 feet of water and several companies hold oil lease rights in 10,000 feet of water. That's 10,000 feet of water as in 560 feet short of two miles. That's like stacking seven and a half New York World Trade Centers, one on top of another, just to get from the bottom of the drilling platform to the sea floor. Then, producers often have to drill 15,000 to 20,000 feet further beneath the Earth's surface to find what they are looking for - potentially huge reserves of oil and gas. It's these "elephant reserves" that make it all, the work and the money, worthwhile. Estimates are that the deepwater Gulf of Mexico holds 10 billion to 15 billion barrels of recoverable oil. Deepwater oil production is fabulously expensive, much more so than drilling onshore or in shallow water, but deepwater reservoirs offset some of that expense by flowing at great rates. A highly productive well onshore or in shallow water may flow at 3,000 barrels to 4,000 barrels per day. Its deepwater cousin may flow at up to 30,000 barrels per day, "which is unheard of in this country," says Bob Stewart, president of the National Ocean Industries Association (NOIA), a trade organization representing the domestic offshore oil and gas industry.

Hudgins, CM Jr. 1991. Usage of chemicals in offshore oil and gas production. Monitoring Water In The 1990's: Meeting New Challenges. American Society For Testing And Materials, Philadelphia, PA (USA). pp. 343-359

This paper reviews the chemicals used to help control many operating problems encountered in U.S. offshore oil and gas production. The discussions covers the production treating chemicals, gas processing chemicals, and stimulation and workover chemicals. A brief discussion of each chemical group presents its purpose, solubility properties, primary generic chemical types, and typical use concentrations. A portion of these chemicals will dissolve in the produced water, with the remainder going with the oil. Most of the water produced with oil and gas in offshore operations in the U.S. is treated to remove dispersed oil and grease, then discharged to the sea. The discussion on environmental aspects summarizes information on the aquatic toxicity, solubility, and typical treatment and discharge concentrations for chemicals used for each purpose.

Jarlan, GE. 1981. Hibernia Oil Field development. A prestressed concrete drilling and production gravity platform. Proceedings Of The Symposium Production And Transportation Systems For The Hibernia Discovery. pp. 18-34

A pre-stressed Concrete Gravity Platform is proposed for the development of the Hibernia Oil Field. The conceptual features of this platform are similar to those adopted for the Ekofisk One Million Bbl Unit in the North Sea. The deck area is equal to about 13,000 sqm. and the structure allows for drilling and production operations. A submerged rubble-mound protection extending over a given length is contemplated. It is aimed at dampening the detrimental effects due to icebergs. Inasmuch as a three-dimensional model study could be carried out in a Hydraulics Laboratory equipped with an ice tank, it could be possible to optimize the project, taking into account waves, icebergs impact and pack-ice effects.

Jones, C. A. 1999. Compensation for natural resource damages for oil spills: a comparison of US law and international conventions. INCAE, Alajuela, Costa Rica. International Journal of Environment and Pollution. **11(1)**:86

The basic measure of natural resource damages in USA environmental liability statutes is the cost of restoring the injured resources, plus compensation for the interim loss of resources from the time of injury until their full recovery. In contrast, until 1996, the international Convention Protocols addressing liability for accidental oil spills did not hold the responsible party liable for damages to natural resources, except to compensate for lost profits and earnings of commercial users of the resources. Recent developments, however, suggest that international and USA laws are converging. In the 1996 regulations implementing the natural resource liability provisions of the USA Oil Pollution Act (OPA), natural resource damages are quantified as the costs of a Restoration Plan designed to return resources to baseline and to compensate for interim losses. The 1992 international Convention Protocols, which entered into force in May 1996, include the costs of resource 'reinstatement' measures, though a clear definition of the scope of 'reinstatement', consistent with the restoration concepts in the OPA regulations, could provide an inclusive measure of damages for environmental harm. Furthermore, such a measure would not contravene the policy, previously articulated by the international organization administering the compensation regime, that only losses quantifiable in financial terms may be claimed.

Kennicutt, MC, Boothe, PN, Wade, TL, Sweet, ST, Rezak, R, Kelly, FJ, Brooks, JM, Presley, BJ, and Wiesenburg, DA. 1996. Geochemical patterns in sediments near offshore production platforms. Canadian Journal of Fisheries and Aquatic Sciences **53(11)**:2554-2566

Patterns of the geochemical characteristics of sediments adjacent to three production platforms (22-150 m water depths) in the northwestern Gulf of Mexico were determined by the presence of the structure, the amount and type of materials discharged from the structure, and the local hydrographic setting. Sediments close to the platforms (<500 m) were enhanced in coarse-grain materials primarily derived from discharged muds and cuttings. Hydrocarbon and trace metal (Ag, Ba, Cd, Hg, Pb, and Zn) contaminants were associated with these coarse-grain sediments. Contaminants were asymmetrically distributed around each platform in response to the prevailing currents. Contaminant concentrations at most locations were below levels thought to induce biological

responses. At a few locations close to one platform, trace metal (i.e., Cd, Hg) concentrations exceeded levels thought to induce biological effects. In deep water (>80 m), sediment trace metal contaminant patterns were stable over time frames of years. A few metals (Pb, Cd) exhibited evidence of continued accumulation in sediments over the history of the platform.

Kingston, PF. 1990. Impact of offshore oil production installations on the benthos of the North Sea. International Counc. for the Exploration of the Sea, Copenhagen (Denmark). ICES Council Meeting 1990 (Collected Papers)., ICES, Copenhagen (Denmark). 6 pp

Biological monitoring around the offshore oil production platforms has now been going on for over 15 yr resulting from the change from predominantly exploration and production well drilling to oil production and from the change in government legislation relating to drilling activity and monitoring. The most common approach currently used to monitor the impact of oil field development is to sample the seabed by 0.1 m super(2) grab sampler on a transect along the prevailing current direction. Samples are usually taken at 200, 500, 800, 1200, 2500 and 5000 m from the installation. Gross effects on the benthic communities are detectable up to 500-1000 m from the platform, the precise extent depending upon the drilling history of the platform and the type of drilling muds used.

Kingston, PF. 1992. Impact of offshore oil production installations on the benthos of the North Sea. ICES journal of marine science. **49(1)**:45-53

Input of contaminants into the sea associated with offshore oil drilling and production include accidental spillage, discharge of cuttings and discharge of production water. Of these, oil discharged on drilling cuttings is by far the greatest source of oil pollution in the North Sea from these operations, having peaked in 1985 at 25,880 tonnes. The response to the seabed fauna to these inputs has been shown to follow established patterns in which there may be high individual abundance of a few species close to the source of contamination (organic enrichment effect) or a reduced number of individuals with few species close to the installation (smothering or toxic effect). Diversity shows a similar pattern to species richness, both are low in the immediate vicinity of the installation and, in most cases, attaining preoperational levels within 2000. High levels of hydrocarbon contamination have also been shown to be concentrated around installations. There are indications that a fall in diversity can be expected when total hydrocarbon concentrations in the sediment reach 50-60 ppm. There is also increasing evidence to suggest that for some areas where there has been intensive drilling/production activity (e.g. Shetland Basin), there has been a significant rise in hydrocarbon levels in the sediment at distances between 5 and 10 km from installations.

Knott, T. 1998. North Sea keeps tight hold on technology. Pet. Rev. **52(620)**:14-16

New technology solutions such as subsea systems and floating production units have breathed new life into North Sea oil and gas activities. Adding to this, the fundamental

shift in research and development from oil companies to major contractors and the current trend for large-scale mergers in the service and supplies sector have brought a sharper competitive business edge to the industry. This article reviews the latest technological developments in the North Sea oil and gas industry.

Krause, PR. 1994. Effects of an oil production effluent on gametogenesis and gamete performance in the purple sea urchin (Strongylocentrotus purpuratus Stimpson). Environmental Toxicology and Chemistry. **13(7)**:1153-1161

Adult organisms subjected to chronic discharges from a point source of pollution may exhibit several sublethal responses. One such response is the impairment of gamete production. This may be expressed in the amount and/or quality of gametes produced by adults. In this study the effects of chronic exposure to produced water (an oil production effluent) on the gametogenesis and gamete performance of the purple sea urchin (Strongylocentrotus purpuratus Stimpson) were examined using an in situ caging experiment. Adult purple sea urchins were kept in benthic cages arrayed down-field from a discharging diffuser at 13 sites, with distances ranging from 5 to 1,000 m. Cage exposures were maintained in the field for eight weeks, and each cage held 25 animals. Gametogenesis was examined for each sex by comparing a size-independent measure of relative gonad mass as determined by analysis of covariance. Results showed that there was a significant negative relationship between these estimates of relative gonad mass and distance from the outfall for both sexes, indicating that sea urchins living closer to the outfall produced significantly larger gonads. Gamete performance was measured through a fertilization kinetics bioassay that held the concentration of eggs constant and varied the amount of sperm added. The proportion of eggs fertilized under each sperm concentration was determined and the response fit to a model of fertilization kinetics. This experiment showed significant differences in the fertilizability of eggs between cages, and egg fertilizability showed a positive relationship with distance away from the outfall. These findings indicate that although adult sea urchins exposed to a produced water outfall exhibit larger gonads, they suffer a marked decrease in gamete performance.

Law, RJ; Hudson, PM. 1986. Preliminary studies of the dispersion of oily water discharges from North Sea oil production platforms. International Counc. for the Exploration of the Sea, Copenhagen (Denmark). ICES Council Meeting 1986 (Collected Papers). ICES, Copenhagen (Denmark) 11 pp.

Offshore oil production platforms discharge oily water as part of their normal operations. This oily water is of two main types, production and displacement water. This paper reports a preliminary study of the dispersion and dilution of the oily water discharges from two offshore production platforms., Auk A and Forties B, carried out in November 1985. An underwater instrument package which included a fluorometer for in situ measurements of hydrocarbon concentration was towed through the discharge plumes at varying distances downcurrent of the platforms, and at depths of between 5 and 50 m. This allowed measurement of vertical and horizontal concentration profiles within the discharge plumes and estimates of minimum dilution were made from

measurements of oil concentration in the discharge water carried out in the platform. The likely effects of such discharges are discussed.

Leaver, MJ, Murison, DJ, Davies, JM and Rafaelli, D. 1987. Experimental studies of the effects of drilling discharges. Environmental Effects Of North Sea Oil And Gas Developments. Philosophical Transactions of the Royal Society of London, Series B. **316B(1181)**:625-640

The long-term effects of diesel and four different low-toxicity oil-based drilling-mud cuttings on the chemistry and benthic fauna of a marine sediment were compared. Selected parameters monitored at varied intervals throughout the experiment were: redox profiles, sulphide concentrations, hydrocarbon concentration and meiofaunal abundance. Numbers of macrofaunal organisms evacuating the sediments in the seven days after treatment application were also recorded. Mesobenthic meiofaunal abundance was significantly reduced in all cuttings treatments, but effects from individual treatments were indistinguishable. Epi/endobenthic copepod abundance increased markedly in all low-toxicity treatments, and particularly in those with lower oil content, but remained similar to control levels in diesel treatments throughout the experiment. The results show that in equal oil concentrations diesel and low-toxicity oil-based drilling-mud cuttings have indistinguishable effects on sediment chemistry, but that, even after 15 months of weathering, diesel-based cutting are demonstrably more toxic to benthic fauna.

Licari, JP. 1983. Environmental management of Pacific outer continental shelf oil and gas activities by the minerals management service. California Univ., Los Angeles (USA). Dissertation Abstracts International Part B: Science and Engineering. **44(5)**. 249 pp

Critical environmental issues relating to exploration and development in California include protection of coastal resources, effects of routine discharges and onshore air quality impacts associated with drilling and production. Conflicts between the State of California and Department of Interior have developed over Federal regulatory procedures and recent changes in sale and lease management. The Department of Interior has jurisdiction over oil and gas development on the Federal lands. Pre-lease and post-lease management, formerly by the Bureau of Land Management and the Geological Survey, respectively, is now under the newly created Minerals Management Service. The Pacific Outer Continental Shelf Region Office manages these activities in areas offshore from Washington, Oregon, and California.

Ljungblad, DK, Wuersig, B, Swartz, SL and Keene, JM. 1985. Observations on the behavior of bowhead whales (Balaena mysticetus) in the presence of operating seismic exploration vessels in the Alaskan Beaufort Sea. Naval Ocean Syst. Cent., San Diego, CA (USA). Ocs Rep. U.S. Miner. Manage. Serv. 88 pp

The response of bowhead whales (Balaena mysticetus) to active geophysical vessels was observed during the course of 4 field experiments conducted in the Alaskan Beaufort

Sea. September 1984. Conspicuous short-term behavioral changes were observed when active vessels approached to within 10 km of bowheads, with the strongest responses occurring when whales where within 5 km of active vessels. Behavioral responses included shorter surfacing and dive times, fewer blows per surfacing, and longer blow intervals. Total avoidance responses occurred at vessel distances of 1.25 km, 7.2 km, 3.5 km and 3.5 km with associated measured sound levels from the seismic airgun arrays of 152dB, 164dB, 178dB and 163dB, respectively.

Longley,W.L., Jackson,R. and Snyder,B. 1978. Managing oil and gas activities in coastal environments. Publ.by : U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC (USA). 71 p, Biol. Serv. Program Fish. Wildl. Serv. (U.S.)

A summary of a comprehensive technical report. 'The Development of Methods and Standards of Operation to Protect Fish and Wildlife Resources and Supporting Habitats of Coastal Wildlife Refuges During Oil and Gas development' presents general information, based on observation and experience, on the environmental effects of petroleum development activities upon coastal wetlands. It is intended for use by petroleum engineers, land managers, government officials, and others concerned about the preservation of living resources. The management concepts developed from this study were obtained by analysis of management practices on coastal refuges in Louisiana and Texas. This report is intended to assist coastal and land managers in reducing the impacts of oil and gas exploration and production on natural resources. While these management practices were developed for the Gulf Coast Region, they may apply to other coastal area.

Malme, CI, Miles, PR, Miller, GS, Richardson, WJ and Roseneau, DG. 1989. Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. Bolt Beranek and Newman, Inc., Cambridge, MA (USA). OCS/MMS-89/0006. 307 pp

The study compares the relative magnitudes and effects on marine mammals of noise from oil and gas industry activities with noise from other sources in Alaska, USA, outer continental shelf and coastal waters. The study procedure incorporates the receiver, source and path concepts generally used in acoustic analysis. The receiver characterization includes a review of marine mammal distribution in Alaska and a map of the distribution of each major species. Information on species sound production, hearing sensitivity (when known), and observed responses to noise sources is also included. The analysis of noise sources found in the Alaskan marine environment considers natural, industrial, transportation, and cultural sources. Acoustic transmission loss characteristics obtained from measurements and model predictions are used to estimate the effective ranges of the noise sources using available source level information.

Mayerson, D. 1998. Recycling oil industry seismic data for geologic hazards analysis. Taking a Look at California's Ocean Resources: An Agenda for the Future, ASCE, Reston, VA (USA). **1**:504

During the 1970's and '80's, the oil industry collected hundreds of thousands of miles of marine geophysical data for use in the evaluation of offshore oil and gas deposits. Much of this data have lost their value for which they were originally collected because lease sales for oil and gas off the coast of California have been discontinued; with no plans for their resumption at least through 2002. The Minerals Management Service (MMS) and the academic community realize the value of these data for uses other than oil and gas exploration. Though these data were collected so that offshore structures favorable for the entrapment of oil and gas could be identified, their utility also extends to geologic hazard analysis, namely the identification of areas of high earthquake potential. The MMS has recently begun two separate endeavors that will aid in quantifying earthquake potential along the central and southern California coast.

Mayerson, D, Lane, J, Grant, J and Hill, M. 1998. Redefining the federal review process of high energy seismic exploration for oil and gas on Southern California's outer continental shelf: An example of federal, state, local, industry, and public cooperation. Taking a Look at California's Ocean Resources: An Agenda for the Future, ASCE, Reston, VA (USA). **2**:1667-1668

The federal review process of offshore geophysical operations on the Pacific Outer Continental Shelf (OCS) has become increasingly complex and controversial since its inception during the late 1950's and early 1960's. Prior to about 1980, the federal review process consisted of little more than a record keeping exercise and a means of procuring data collected by industry. Today's review process includes a recognition of other users of the OCS and the need to work with all parties that monitor the impacts from OCS activities on the marine and coastal environment. Though commercial fishers, the military, and other Federal and State agencies have been involved in the review process since the early 1980's, some local government agencies and environmental interest groups have not been included in the process.

McDonald, SJ, Willett, KL, Thomsen, J, Beatty, KB, Connor, K, Narayanan, S, Erickson, CM, and Safe, SH. 1996. Sublethal detoxification responses to contaminant exposure associated with offshore production platforms. Canadian Journal of Fisheries and Aquatic Sciences. **53(11)**:2606-2617

Several biomarkers of aromatic hydrocarbon exposure were used to evaluate contamination associated with petroleum and gas development and production in the Gulf of Mexico. Several species of fish and invertebrates were sampled at stations<100 m (near) and >3000 m (far) from the center of three platforms. No significant near/far differences were observed in aryl hydrocarbon hydroxylase (AHH) activity for any invertebrate species. The only significant induction of ethoxyresorufin O-deethylase (EROD) activity in H4IIE cell bioassays was observed in cells dosed with extracts of brown shrimp (Penaeus aztecus) sampled at MAI-686 near station. A sediment contaminant gradient was not detected at this platform. No significant near/far station

differences in EROD and AHH activities, CYP1A mRNA levels, and biliary polynuclear aromatic hydrocarbon (PAH) metabolite concentrations were detected in 16 species of fish. Species-dependent differences in EROD activity and biliary PAH metabolite levels were detected. A radiolabeled nuclear aryl hydrocarbon receptor complex was characterized for two fish species.

McRae, R.N. 1999. Consumption of gasoline and diesel for road transport in Latin America Region. Department of Economics. University of Calgary. mcrae@ucalgary.ca

McRae, R.N. 2000. The Development of natural gas markets in Asia: importance of economic growth. Department of Economics. University of Calgary. mcrae@ucalgary.ca

Currently, sales of natural gas re relatively small in Asia. Lack of supply has been a major problem so the paper will list some of the proposed natural gas supply projects. However, the emphasis will be on examining the factors that affect natural gas consumption. Once long-distance natural gas pipelines are in place or LNG facilities are built, the growth of natural gas markets in Asia will partially be at the expense of substitutable fuels (oil or coal) in the non-transportation end-use sectors, especially the industrial sector, and in power generation. However, for many Asian countries the lack of historical energy price data make it impossible to estimate the degree of inter-fuel substitution between oil or coal and natural gas.

Countries, such as Canada, have experienced the expansion of natural gas consumption once supply was made available. I plan to utilize historical Canadian data to estimate the responsiveness of natural gas sales to economic growth after the supply infrastructure was built in the late 1950s. The estimation of natural gas penetration into the Canadian energy market will be used as an example of what might happen in the long-run as markets mature in Asia.

The paper explores briefly on the reasons for fuel switching: the desire to reduce CO_2 emissions. This could be an important consideration in the choice of an energy fuel. The relationship between CO_2 emissions and economic growth is estimated. If a country wishes to reduce CO_2 emissions without severely affecting economic growth then it might consider a policy to encourage fuel switching from oil or coal to natural gas.

Mes, M.J. 1978. Influence of deck load on platform earthquake sensitivity. Pet. Eng. Int. **50(5)**:76, 80, 83, 84, 88

The fundamental period of a piled jacket drilling and production platform can vary greatly during its lifetime. This holds true in particular for platforms designed for deepwater, rough-weather areas such as the northern North Sea and the Gulf of Alaska. Because of the lengthy periods of bad weather, platforms carry huge supply loads. Often, oil is produced concurrently with drilling operations. The sequence and magnitude of the operations causes total payload on the platform to be about 25,000 tons during the drilling phase, which could reduce to as little as 5000 tons during the production phase.

This payload variation, in extreme cases, can cause a variation of 50% in the fundamental period of the platform. These changes in platform fundamental periods do not need to be taken into account for earthquake design calculations according to the API RP2A section 2.10.f. (American Petroleum Institute Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms, Eighth Edition, April 1977). A reduction in natural period however can cause spectral acceleration (an abstract reference acceleration) to increase almost by a factor of two. It might appear that this could have serious effects on the amount of earthquake energy absorbed in the structure. For a cursory examination of this question, a structural model was chosen. This model simulates a deepwater platform as a 3-deg of freedom system. In this model the three joints may only move in a horizontal direction, thus simplifying the desk top calculator calculations. This restriction does not influence the significance of the results calculated, although it does influence the calculated modal shapes. Initial limitation of the calculations to three structural modes is realistic.

Montagna, P and Harper, DE Jr. 1996. Benthic infaunal long-term response to offshore production platforms in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences. **53(11)**:2567-2588, 1996

Meiofaunal and microinfaunal communities around three gas platforms on the continental shelf (29-157 m water depths) in the Gulf of Mexico were assessed for sublethal effects of chronic exposure to contaminants associated with long-term production. Subsamples of boxcores were collected from 5 distances (30-3000 m) along five radii from each platform during winter and spring in two years. In contrast with platforms in the North Sea, effects were very localized, extending to 100 m from the platforms. Total polychaete and nonselective deposit-feeding nematode density increased near platforms. Amphipod and harpacticoid abundance and diversity and harpacticoid reproductive success declined near platforms. Organic enrichment, contamination by toxicants (e.g., heavy metals and hydrocarbons), and changes in sediment granulometry are confounded along the gradient of distance from platforms. The pattern of community change in both meiofauna and macrofauna around these gas production platforms follows an emerging paradigm of response in which density increases of deposit-feeding polychaetes and nematodes indicate organic enrichment, while density declines of harpacticoids and amphipods indicate toxicity.

Mulder, M, Lewis, WE and Van Arkel, MA. 1988. Biological effects of the discharges of contaminated drill-cuttings and water-based drilling fluids in the North Sea NIOZ-1988-3.

In the study the effects of the discharges of contaminated drill-cuttings and water-based drilling fluids on the macrobenthic fauna were investigated. It was a continuation of a tentative study on biological effects carried out in 1985. Research was undertaken in the Dutch sector of the continental shelf of the North Sea. The study had three aims: Study of short-term effects of the use of oil-based muds (OBM); Study of long-term effects of the use of OBM; and Study of effects of the use of water-based muds.

Munro, PD, Croce, B, Moffat, CF, Brown, NA, McIntosh, AD, Hird, SJ and Stagg, RM. 1998. Solid-phase test for comparison of degradation rates of synthetic mud base fluids used in the off-shore drilling industry. Environmental Toxicology and Chemistry. **17(10)**:1951-1959

A solid-phase degradation test has been developed to assess the fate in marine sediment of synthetic mud base fluids used in the off-shore drilling industry. The degradation rate of an ester-type drilling fluid was investigated at three nominal concentrations in a fine sand. A naturally occurring triester, olive oil, was used as a positive control and a traditional mineral oil served as an example of a poorly degradable substance. Two synthetic drilling fluids, an ester and a blend of n-alkanes with polyalpha olefin and linear-alpha olefin, were compared in a mud and a coarse sand to examine the effect of different sediments on degradability. Glass jars, containing marine sediment that had been homogeneously mixed with test fluid, were placed in troughs in a continuous flow of seawater. Periodically, triplicate jars were sacrificed and, following solvent extraction, the concentration of test fluid remaining in the sediment was determined by gas chromatography with flame ionization detection. The test was able to reproducibly distinguish between easily degradable and poorly degradable fluids. The rate of degradation was concentration dependent; the half-life increased as the nominal concentration increased. The ester was more rapidly degraded than the blended synthetic drilling fluid and degradation was slower in sand compared with mud.

Norway and the Gulf of Mexico in the next ten years. http://www.infield.com/article1.htm

Olsgard, F; Gray, JS. 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. Marine ecology progress series. **122(1-3)**:277-306

Multivariate statistical analyses of data on environmental variables and benthic fauna from 14 oil and gas fields obtained from 24 surveys collected between 1985 and 1993 are presented. At all fields oil-based drilling mud was used. The purpose of this study was to investigate contamination gradients, assess effects on benthic fauna both spatially and temporally and to evaluate measures such as diversity indices, indicator species and multivariate analysis techniques in assessment of pollution. Results from analyses of baseline surveys of environmental variables and fauna were characterized by a lack of distinct gradients in station placement, having a typical shot-gun pattern in PCA-, DCA- and MDS-ordination analyses. Likewise there was no consistency in which environmental variables correlated with the fauna. Contamination was assessed using all the physical and chemical data in classification and PCA-ordination analyses. Clear patterns were found using 4 categories, conveniently termed initial, moderate, severe and gross. The categories were usually apparent as rings radiating from the platform. Initial contamination of the outermost areas at most fields was shown as elevated levels of barium and total hydrocarbons (THC) and sometimes also by elevated levels of zinc, copper, cadmium and lead. Three fields were studied in particular and showed contaminated areas of over 100 km super(2) (Valhall), over 15 km super(2) (Gyda) and

over 10 km super(2) (Veslefrikk). After a period of 6 to 9 yr contamination had spread, so that nearly all of the outermost stations 2 to 6 km away from the platforms showed evidence of contamination. Thus, the existing sampling design is no longer suitable for assessment of the area contaminated. Effects on the fauna showed, as with contamination, 4 categories. Analyses linking fauna and environmental variables indicated that the effects were mainly related to THC, barium and strontium, but also to metals like zinc, copper, cadmium and lead, which are all discharged in drill-cuttings. Effects on the fauna closely followed the patterns of contamination with only a few stations at each field that were contaminated not showing effects. Thus the areas showing effects were only slightly less than the areas contaminated. Subsequent to cessation of discharges biodegradation of oil and reduced concentrations of THC were observed. Yet there was an extension of areas where the fauna was affected several years after cessation of drill-cutting discharges. This may indicate that barite and related compounds associated with the discharges also have an environmental impact. However, preliminary results from fields using only water-based mud clearly indicate a reduction in environmental contamination and biological impact, compared to effects reported here, for oil-based drill-cuttings. Diversity indices applied to the data did not show the extent of effects and such indices alone should not be used to interpret changes. The consistent patterns that the multivariate techniques were able to detect showed that these methods were far superior. Analyses of the initial effects on the fauna showed that there were no consistent patterns in changes in species composition over fields or time, and thus the search for 'universal' sensitive indicator species does not seem to be rewarding. Yet under gross effects of pollution there were consistent patterns with the same species dominating. Finally, the initial effects of pollution included severe reductions in organisms that are key components of the benthic communities and also food for bottom-living fish, and are thus ecologically important. The new fauna which establishes in the contaminated sediments close to platforms, often with high abundance, will probably be less valuable as a food source for fish populations since it is of small size and lives sub-surface.

Osmaston, M.F. and Hobson, G.D. (ed.). Some fundamental aspects of plate tectonics bearing on hydrocarbon location. *In*: Developments in petroleum geology.

The interpretive framework of plate tectonics is carefully reassessed and considerably extended with particular regard to the problems of hydrocarbon exploration. It is found that the seismic low-velocity zone lies wholly within the plates, which are thus very much thicker and stiffer than previously recognised. The consequences impinge upon surface and near-surface phenomena to a quite remarkable degree, offering (inter alia) major and unifying advances in the interpretation of basins, whether in orogenic settings, at ocean margins, or within continents. Specifically, the persistent and episodic differential epeirogenic movement of block-and-basin crustal mosaics is shown to be characteristic of basin complexes formed by limited plate separation at a much earlier time (even as long ago as Late Precambrian). Island inliers (micro-continents) detached at that time provide buried structural highs important for hydrocarbon accumulation. Extremely precise (about 5 km) reconstructions are achievable. Plate stiffness makes epeirogenic processes at plate edges felt at great distances from them, often causing flexural failure, intra-plate rifting, intraplate volcanism and further epeirogeny. Thick

plates enhance thermal epeirogenic effects, enable shelf emplacement of ophiolite slices to occur during early separation, explain certain features of the subduction process, and shed light on the incidence and petrogenetic mechanisms of intraplate volcanism. Correct treatment of plate thermal epeirogeny shows the previous wholly-vertical contraction/expansion requirement to be erroneous. The plate tectonics of the Phanerozoic of north-western Europe and the post-Palaeozoic of the Middle East are among the examples discussed. With this greatly increased relevance and precision, plate tectonic analysis is clearly capable of playing a valuable and detailed part in hydrocarbon exploration, contributing directly both to the precise delineation of basement structural outlines and to the interpretation of subsequent structural, sedimentary and thermal evolution.

Panzer, D and Weisbecker, P. 1998. The development and use of a computerized system to examine trends in the components of produced water discharges from outer continental shelf oil and gas platforms. Taking a Look at California's Ocean Resources: An Agenda for the Future, ASCE, Reston, VA (USA). **1**:480-490

The Minerals Management Service's Pacific OCS Region (POCSR) has had an historic need for data on the types, volumes, and trends in the quantities of components of produced water and the toxicity of drilling muds discharged by the offshore oil and gas platforms. These data are important in working with local agencies to address environmental concerns, as well as addressing the National Environmental Policy Act (NEPA) requirements that decisions be made based on analysis of environmental impacts. This project could provide information to the State of California in its efforts to develop a comprehensive program to monitor the quality of ocean waters and coastal streams. To analyze these data, the POCSR has developed a computerized system that enables the user to examine any produced water or drilling fluid discharge over time on a single or multiple platform, component, or mass-emission basis. QuattroPro, a spreadsheet program, was used for initial data entry and to perform primary analyses. The basic spreadsheet format is discussed, along with examples for both produced water and drilling fluid discharges. To further facilitate examination of statistical trends, export to a database such as Paradox can be performed. This information can be used for NEPA analyses, to indicate facilities where more or less sampling is needed, and to answer general questions from the public or other agencies concerning discharge characteristics and impacts on water quality.

Parker, HD, White, IC and Moller, TH. 1987. Impact of oil on coastal industries. Fate And Effects Of Oil In Marine Ecosystems. Proceedings Of The Conference On Oil Pollution Organized Under The Auspices Of The International Association On Water Pollution Research And Control (Iawprc) By The Netherlands Organization For Applied Scientific Research Tno Amsterdam, The Netherlands, 23-27 Feb 1987. pp. 221-223

The effects of oil spills on mariculture and industrial installations in the coastal environment are discussed. The impact of oil on marine life may be caused by its physical nature or by chemical components of the oil; nori production and mussel

culture are considered with respect to the problem of oil contamination. The effect of oil contamination on industrial intakes, such as those in electricity generating stations and desalination plants, is also discussed briefly.

Peterson, CH, Kennicutt, MC, Green, RH, Montagna, P, Harper, DE Jr, Powell, EN, and Roscigno, PF. 1996. Ecological consequences of environmental perturbations associated with offshore hydrocarbon production: A perspective on long-term exposures in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences **53(11)**:2637-2654

A synthesis of the literature on benthic responses to marine pollution suggests that macroinfaunal and meiofaunal communities exhibit repeatable patterns of response to sedimentary contamination generally detectable at high taxonomic levels. These responses appear to be jointly driven by intrinsic physiological and ecological characteristics of higher taxa, such that crustaceas and echinoderms are sensitive to toxics whereas polychaetes, oligochaetes, and nematodes are enhanced by organic enrichment. Application of this model to the GOOMEX results implies involvement of both toxicity and organic enrichment. Results of toxicity tests and comparisons of observed contaminant concentrations to known effects levels imply that metals drive the toxicity response. Long-lasting effects of drilling activity exist in the sedimentary environment around gas production platforms. Dual effects of toxicity and organic enrichment probably drive readily detectable responses in benthic meiofauna and macroinfauna to 100-200 m, and the failure to detect evidence of exposure or sublethal impacts on fishes and most larger invertebrates is a joint consequence of their mobility over the relevant scales of environmental change and their neglible exposure to hydrocarbons and other contaminants.

Petrazzuolo, G, Michael, AD, Menzie, CA, Cole, RH and Golan, RG. 1985. Assessment of environmental fate and effects of discharges from offshore oil and gas operations. Technical Resources, Inc., Rockville, MD (USA). Misc. Rep. Ser. U.S. Environ. Prot. Agency.

The overall objectives of this study are to characterize and assess the fate and effects of discharges from offshore oil and gas drilling and production activities. Four specific objectives were outlined by EPA: Present overall conclusions on the fate and effects of drilling fluids and cuttings discharged to the marine environment; Describe types and quantities from offshore drilling and production; Describe transport phenomena to which discharges will be subjected, including physical, chemical, and biological processes; and present information on the acute and chronic toxicity of drilling fluids and produced waters on marine organisms.

Petro-Canada Inc. 1983. Offshore Queen Charlotte Islands Initial Environmental Evaluation. Volumes I, II and III

Piltz, FM. 1986. Monitoring long-term changes in biological communities near oil and gas production platforms. Oceans '86 Conference Record: Science-Engineering-Adventure. Vol. 3. Monitoring Strategies Symposium. pp. 856-861

The U.S. Department of the Interior Minerals Management Service Pacific OCS Region began a monitoring program conducted through the Environmental Studies Program in 1984 for the long-term effects of oil and gas production platforms on biological communities. Phase I, a broad scale geographic reconnaissance and baseline survey, has been conducted for the Santa Maria Basin offshore California where oil and gas production will begin in the near future. Phase II is beginning and will focus on time series measurements of a wide variety of biological, physical and chemical parameters at platform sites and comparison sites.

Rattner, BA, Capizzi, JL, King, KA, LeCaptain, LJ and Melancon, MJ. 1995. Exposure and effects of oilfield brine discharges on western sandpipers (Calidris mauri) in Nueces Bay, Texas. Bulletin of Environmental Contamination and Toxicology. **54(5)**:683-689

Discharge of oilfield brines into fresh and estuarine waters is a common disposal practice in Texas. Petroleum crude oil (PCO) extraction from underground stores includes the removal of a significant amount of water along with the oil. Several methods may be used to separate the oil and water fractions, including tank batteries, heat separation, and skimming ponds. Disposal of the resultant produced water (oilfield brine) may be accomplished by deep-well injection or discharge to surface waters. In Texas, an estimated 766,000 barrels of oilfield brine were discharged daily into tidal waters in 1979 (Liebow et al. 1980). The maximum concentration for oil and grease in these discharges permitted by the Texas Railroad Commission is 25 ppm. Several studies have shown that oilfield brines are toxic to a wide range of marine life, yet little is known about their effects on birds and mammals. Exposure to petroleum in oilfield wastes could evoke toxicological effects in some waterbird species. Avian responses to PCO exposure are highly variable, including cessation of growth, osmoregulatory impairment, endocrine dysfunction, hemolytic anemia, altered blood chemistry, cytochrome P450 induction, reduced reproductive success, and mortality. Oilfield brine discharges may soon be the largest and most pervasive source of contaminants entering Texas estuaries. Migratory and resident birds feeding in the vicinity of discharge sites may be ingesting food items contaminated with petroleum hydrocarbons, heavy metals and salts in sufficient quantities to evoke toxicity. The present study of wintering western sandpipers (Calidris mauri) that feed and roost near discharge sites sought to examine oilfield brine exposure and effects through quantification of contaminant burdens, morphological characteristics, and cytochrome P450-associated monooxygenase activities.

Rauck,G., Tiews,K. and Mann,H. (eds.). 1979. Oil and gas exploration, production and transport and related problems for fisheries. In: Problems of coexistence of fishery and other branches of industry in exploitation of the North Sea German continental shelf/Probleme der Koexistenz von Fischerei und anderen

Wirtschaftszweigen bei der Nutzung des Deutschen Festlandsockels der Nordsee. p.82-97. Arb. Dtsch. Fisch.-Verb. (No. 27)

Oil and gas exploration has several effects on fisheries: seismic reflection measurements can have severe consequences on organisms; boring rigs which can hinder the fishing vessels; and dumped equipment can foul nets are but 3 examples. A further problem is badly laid pipelines which are not only a physical obstacle but are not protected against being pierced by trawling gear, with possible disastrous consequences. Strict, enforcable measures are therefore suggested for the oil industry.

Reed, DC., Lewis, RJ. and Anghera, M. 1994. Effects of an open-coast oil-production outfall on patterns of giant kelp (Macrocystis pyrifera) recruitment. Marine biology. **120(1)**:25-31

Field and laboratory experiments were used to investigate the spatial scale of benthic effects of an active nearshore produced-water (= aqueous wastes of oil and gas production) outfall on various components of recruitment in the giant kelp Macrocystis pyrifera. Results showed that discernible effects on all parameters measured were limited to areas very close to the outfall (<50 m). Zoospore production in sporophytes transplanted to varying distances from the diffusers did not vary in a systematic way. Survival and successful reproduction (i.e., sporophyte production) of outplanted gametophytes varied significantly among experimental dates. Performance of these parameters was significantly reduced only at the site nearest the diffusers (5 m away). Poor gametophyte survival near the outfall may have resulted from exploitative competition with Beggiatoa (a fast-growing filamentous marine bacteria that exploits areas high in hydrogen sulfide, an abundant constituent of the produced-water effluent) rather than from toxicity of produced water. Laboratory assays indicated that gametophyte reproduction and subsequent sporophyte production were inhibited at levels likely to occur within the near vicinity of the diffusers. Nonetheless, field data indicate that the lack of sporophyte production near the diffusers probably resulted from factors affecting gametophyte survival.

Richardson, WJ, Greene, CR, Koski, WR, Malme, CI and Miller, GW. 1990. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska-1989 phase: Sound propagation and whale responses to playbacks of continuous drilling noise from an ice platform, as studied in pack ice conditions. LGL Ltd., King City, ON (Canada). OCS Rep. U.S. Miner. Manage. Serv. 306 pp

The report concerns the effects of underwater noise from simulated oil production operations on the movements and behavior of bowhead and white whales migrating around northern Alaska in spring. 1989 was the first year of a multi-year study. An underwater sound projector suspended from pack ice was used to introduce recorded drilling noise and other test sounds into leads through the pack ice. These sounds were received and measured at various distances to determine the rate of sound attenuation with distance and frequency. The movements and behavior of bowhead and white whales approaching the operating projector were studied by aircraft-and ice-based

observers. Some individuals of both species were observed to approach well within the ensonified area. However, more data are needed before firm conclusions can be drawn.

Richardson, WJ. 1991. Effects of noise on marine mammals: Executive summary. LGL Ecological Research Assoc., Bryan, TX (USA). OCS Rep. U.S. Miner. Manage. Serv. 28 pp

The report is review of published and unpublished literature concerning the effects of manmade noise on marine mammals. Emphasis is given to underwater sounds, but airborne sounds are considered as well. Special attention is given to noise-emitting activities associated, directly or indirectly, with offshore hydrocarbon exploration and development, since that is a dominant interest of the U.S. Minerals Management Service, sponsor of the review. However, reactions of marine mammals to noise from all types of human activities are considered. Special attention is given to species of marine mammals and types of human activities that occur in waters around the United States. However, relevant literature from elsewhere is reviewed.

Richardson, WJ, Greene, CR, Hanna, JS, Koski, WR and Miller, GW. 1997. Acoustic Effects of Oil Production Activities on Bowhead and White Whales Visible during Spring Migration Near Pt. Barrow, Alaska, 1991 and 1994 Phases: Sound Propagation and Whale Responses to Playbacks of Icebreaker Noise. LGL Ltd., King City (Ontario).; Greeneridge Sciences, Inc., Santa Barbara, CA., Minerals Management Service, Anchorage, AK. Alaska Outer Continental Shelf Office.

This report deals primarily with data collected in the springs of 1991 and 1994. The specific objectives of the 1991 and 1994 phases of the project were similar to those in 1989-90, with the main exception being that top priority was given to work involved in playbacks of variable icbreaker sounds to bowhead whales. The 1991 and 1994 icebreaker playback data allow use to conclude that exposure to a single playback of variable icebreaker sounds can cause statistically but probably not biologically significant effects on the movements and behavior of migrating bowheads visible in the open water of nearshore lead systems during spring migration east of Pt. Barrow. Effects of an acutal icebreaker on migrating bowheads, especially mothers and calves, could be biologically significant in the Chukchi spring lead.

Sanders, PF and Tibbets, PJC. 1987. Effects of discarded drill muds on microbial populations. Environmental Effects Of North Sea Oil And Gas Developments. Philosophical Transactions of the Royal Society of London, Series B. **316B(1181)**:567-585

Drilling operations from platforms in the North Sea result in the production of large quantities of drill cuttings. These are a variable mixture of rock chippings, clays and original drilling fluids. Drilling mud is cleaned on the platform to remove rock chips before re-use of the mud. The rejected fraction from the clean-up plant (the cuttings) contains some of the base drilling fluid, and this can lead to an organically rich input to the sea-bed. Cuttings are discarded immediately underneath the platform jacket and

thus build-up over the natural seabed sediment. In many cases this cuttings pile may cover considerable areas of seabed, leading to seabed biological effects and potential corrosion problems.

Schapery,R.A., Dunlap,W.A. 1978. Prediction of storm-induced sea bottom movement and platform forces. OTC-3259 SO: Source Proc. Offshore Tech. Conf, Publ. by Offshore Technology Conference; Dallas, TX (USA). p. 1789-1796

A procedure is described for calculating storm wave induced movement of soft sea floor sediment and prediction of the associated drag forces exerted on offshore structures used in the production of gas and oil. The analytical model used to predict movement and the state of stress in the sediment is based on a rigorous viscoelastic analysis and a generalization of the method of equivalent linearization. In contrast the previously published work in this area, the procedure described accounts for the effects of soil inertia, nonlinear material damping, rate-dependence of the soil properties, and down-slope movement induced by wave action. Representative predictions of the sea bottom movement are shown. Finally, experimental work performed in support of this analysis and used to develop a model for predicting forces on cylinders is summarized.

Schmitt, RJ, Carr, MH and Williamson, B. 1998. Southern California Educational Initiative and Coastal Marine Institute: Long-term environmental, social and economic consequences of offshore oil and gas production. Taking a Look at California's Ocean Resources: An Agenda for the Future, ASCE, Reston, VA (USA). **2**:1731-1732

During the past decade, the Environmental Studies Program of the Minerals Management Service recognized the need for more and better information on long-term environmental and social effects of OCS oil and gas production. Additionally, the agency has sought mechanisms to foster innovative, peer-reviewed science, and to more effectively engage academic scientists to word on questions relevant to MMS. The agency implemented two programs in the Pacific Region to accomplish these goals, which are entitled the Southern California Educational Initiative (SCEI) and the Coastal Marine Institute (CMI). The overall goal of the 5-year programs is to develop new information on long-term social and environmental effects of oil and gas production in the Pacific Region, Outer continental Shelf of the United States. This will be achieved primarily through research studies that focus on broad, unresolved issues of regional and national importance, the results of which will be published in the peer-reviewed literature. A complementary goal is to develop a "pool" of scientific expertise capable of resolving current and future problems arising form such coastally-dependent enterprises as offshore oil and gas development. This will be realized by attracting academic scientists to conduct original research on issues appropriate to MMS, and by a variety of mechanisms to involve undergraduate, graduate and post-graduate students in a broad array of research activities.

SPARK 1993. Ocean Opportunities for the West Coast of Canada

Stegemeier,R.J. and Simonett,D.S. 1979. The impact of oil and gas production from the marine environment: an analysis of the record. Presented at: Marine Sciences and Ocean Policy Symposium; Santa Barbara, CA (USA) In: Marine Sciences and Ocean Policy Symposium, Santa Barbara, CA (USA). A definition of the issues and a search for a consensus on multiple uses. A symposium on the occasion of the inauguration of Robert A. Huttenback as Chancellor University of California at Santa Barbara.

The annual load of petroleum hydrocarbons which reach the sea comes from various petroleum sources. Transportation (tankers, etc) is by far the worst offender with river and urban runoffs a close second. Spills from offshore oil production are almost insignificant. It is not well recognized that natural seeps put about 7.5 times more hydrocarbons into the seas than do spills from offshore oil production. The oceans also contain hydrocarbons that come from biogenic processes occurring in the sea and on the sea bottom. The recovery of polluted areas varies depending on the flushing of the polluted area, the type of sediment and the degree of isolation of its ecosystems and the kinds of organisms that form them. Oil lingers for different periods in different locations, and accordingly recovery times vary. A whole new area of scientific research, that related to oil spills, their effects, their fates, their clean-up and their prevention, has come into being during the past ten years. As a result of these efforts, improvements have been made in means for containing oil spills (except in high seas), less toxic dispersants, new efficient skimmers for taking oil off water surfaces, selection and development of suitable methods for cleaning beaches and last but not least, ways to minimize offshore oil spills.

Street, GT and Montagna, PA. 1996. Loss of genetic diversity in Harpacticoida near offshore platforms. Marine Biology. **126(1)**:271-282

Offshore oil and gas production platforms can be a source of chronic stress that could lead to sublethal impacts on resident benthic organisms. In June 1993 and January 1994, genetic diversity of Harpacticoida (Copepoda) living proximal to operating, offshore platforms in the Gulf of Mexico was estimated to test if platforms are associated with strong selective pressures. Because harpacticoids have short generation times and direct benthic development, they are suitable organisms for examining population responses. Genetic diversity was estimated by comparing restriction fragment length polymorphisms generated from mitochondrial DNA amplified by the polymerase chain reaction on individuals of five species (Cletodes, Enhydrosoma pericoense, Normanella, Robertsonia and Tachidiella) Populations living at Near regions (stations <50 m from a platform) had significantly less haplotype diversity than populations of the same species living at Far regions (stations >3 km from a platform). The levels of haplotype diversity exhibited by the Far populations were similar at three different platforms located hundreds of kilometers apart. The differences in haplotype diversity between Near and Far regions were the result of a higher proportion of dominant haplotypes, and a loss of less common haplotypes. Haplotypic diversity was inversely correlated with a multivariate measurement of levels of sediment contaminants. The pattern of haplotype diversity on the Gulf of Mexico continental shelf seems to consist of a uniform level of

haplotype diversity, punctuated by islands of lower diversity around oil and gas platforms. The selective pressures that lead to a loss of genetic diversity may be the result of contaminants, other differences in the physico-chemical environment, or disturbance in general.

Stroemgren, T, Soerstroem, SE, Schou, L, Kaarstad, I, Aunaas, T, Brakstad, OG and Johansen, Oe. 1995. Acute toxic effects of produced water in relation to chemical composition and dispersion. Marine environmental research. London. **40(2)**:147-169

The total discharge of produced water in the Norwegian sector of the North Sea is expected to increase to 90 x 10 super(6) m super(3) within the year 2000, with nearly all of this originating from oil production. Produced water from three oil fields in this sector showed large differences in chemical composition and toxicity towards four test organisms (Skeletonema costatum, Mytilus edulis, Abra alba, Crassostrea gigas). Values of EC sub(50) for these organisms ranged from 0.2 to ca 30% of produced water in the test medium. Biodegradation of the produced water changed the chemical composition and generally reduced the toxicity. Model data for dispersion combined with toxicity estimates indicates that acute toxicity should be expected only in the immediate vicinity of the outlets, while at a distance (i.e. >2 km) toxic effects are considered negligible.

Talabani, S, Hareland, G, and Islam, M. R. 1999. New additives for minimizing cement body permeability. Energy Sources: Journal of Extraction, Conversion, and the Environment. **21(1-2)**:163. http://www.tandf.co.uk

An experimental investigation was carried out with a new array of cement additives, replacing some of the currently used ones. In this study, the cement slurry pressure was monitored during the setting of the cement. Two time-cycles of cement expansion and contraction were observed. This is due to the individual contribution of each component in the cement mixture. To obtain the optimum lightness of the cement, final contraction in the cycle is crucial for blockage of gas migration. Concentrations of the additives were obtained experimentally in this study for which the cyclic pressure behavior of the cement was optimized and the permeability reduced for the best final cement results. The parameters investigated in this study were as follows: pressure applied on the slurry with time, compressive strength, and permeability of the set cement. The major causes of the early microfractures are the incomplete cement-water reaction, low compressive strength of the set cement and the sudden change in the hydrostatic pressure as the cement changes its phase from a liquid to a solid state. The fluid loss and free water content were measured and controlled for each sample. Three new cement additives were investigated, one was used to eliminate the microannulus with the pipe while the other two were used to eliminate the microfractures within the cement body. An appropriate amount of Ironite Sponge concentration eliminated the microannulus with the pipe. The optimum amount of synthetic rubber powder needed during the optimum two-cycle expansion-contraction process was also obtained under reservoir conditions. The Anchorage clay concentration in the mixture that migrates for a limited time minimizes the cement body pores. This concentration can also be optimized. This paper

reports the appropriate amounts of X-C polymer, Anchorage clay, Ironite Sponge, and synthetic rubber needed to optimize the compressive strength and eliminate both microfracture and microannulus. There are certain limits to the amount and type of synthetic rubber powder for which microfractures are eliminated. This article reports an experimental approach that can be used to eliminate gas migration through a cement design that is environmentally safe and inexpensive, using recyclable materials.

Terzaghi, C, Buffagni, M, Cantelli, D, Bonfanti, P and Camatini, M. 1998. Physical-chemical and ecotoxicological evaluation of water based drilling fluids used in Italian off-shore. The International Symposium On Integrated Ecotoxicology From, Elsevier Science Ltd., Pergamon. Chemosphere. **37(14-15)**:2859-2871

In order to evaluate the effects on the marine ecosystem caused by an eventual discharge into sea of water based drilling fluids, as current legislation allows, chemical and ecotoxicological analyses were performed on the most common drilling muds and products used in Italian off-shore activities. The chemical analysis on drilling fluids involved the leaching test and the measurement of total content of heavy metals, whereas biodegradation tests were performed on the products used in mud's formulations. As for ecotoxicological evaluation, two marine organisms, the crustacean Artemia salina and the diatom Phaeodactylum tricornutum, were selected to determine the LC sub(50) and the EC sub(50) respectively.

Thomas, WA. 1986. North Sea field developments: Historic costs and future trends. Journal of Petroleum Technology. **38(12)**:1211-1220

This paper reviews U.K. Continental Shelf (UKCS) field developments to date for technical features, development time scales, and economics. Current UKCS field-development trends are identified, including use of subsea completions and floating production platforms (FPP's) for development of small deepwater fields. Economic comparisons are presented for a range of field developments under existing U.K. tax and fiscal regimes. The effects of unstable oil prices on rates of return (ROR's) are discussed, together with the effect of tax changes on field economics.

Thompson, W-A. 1999. Drilling for Jobs. B.C. Report. July 12. p. 36-38.

B.C.'s offshore oil and gas deposits are an untapped economic bonanza, but environmental fears are keeping an exploration moratorium in place – for now.

Tkalec, M., Vidakovic-Cifrek, Z. and Regula, I. 1998. The effect of oil industry "high density brines" on duckweed Lemna minor L. Chemosphere. **37(13)**:2703-27

Duckweed Lemna minor L. is a suitable plant model for toxicity evaluation of many substances due to its small size, rapid growth and ease of culture. Saturated water solutions of calcium chloride and calcium bromide and their 1:1 mixture are commonly used as "high density brines" for pressure control in oil wells. These solutions were added in Hoagland's nutrient medium in amounts appropriate to achieve 0.5%, 1.0%,

1.5% and 2.0% (v/v) dilutions and after two weeks of exposure the effect of tested chemicals on growth was estimated by counting fronds, measuring fresh and dry weights and determining total surface area of plants. Chlorophyll and carotenoid content in Lemna minor was also measured. Additionally, anthocyanin content in Spirodela polyrrhiza (L.) Schleiden was determined. During 14 days of exposure tested chemicals in lower concentrations (0.5%, 1.0% and 1.5% v/v) promoted the growth of Lemna minor, but they inhibited it in the highest (2.0% v/v). With increased concentration of tested solutions the concentrations of chlorophyll a and chlorophyll b were correspondingly higher in comparison with the control. Total carotenoid content and chl a/chl b ratio were also increased. The highest anthocyanin content in lower epidermis of Spirodela polyrrhiza was noticed after the treatment with media containing 2.0% (v/v) CaCl sub(2) and 1:1 mixture of CaCl sub(2) and CaBr sub(2), but lower concentrations of all three tested solutions also resulted in anthocyanin content increase.

Virmani, A. 1985. Tax and contractual arrangements for the exploitation of natural resources. International Bank for Reconstr. and Dev., Washington, DC (USA). 154 pp

The paper analyzes the efficiency of several tax-contract systems, such as the resource rent tax, production share system, and royalty. Account is taken of their incentive effects on behavior of firms under different economic and geological conditions, with particular emphasis on areas where prospects are relatively poor. The paper shows the strengths and weaknesses of systems widely used or recommended for oil exploration and production in developing countries. An analysis of the problem of nationalization risk is also carried out, and some light shed on which of these systems is best able to cope with the problem.

West Coast Offshore Exploration Environmental Assessment Panel (WCEEAP). 1986. Offshore Hydrocarbon Exploration

Will, G. 1998. Canadian production set to boom. Pet. Rev. **52(618)**:30-31

On both the east coast of Canada and in the western part of the country, the next five years promise significant changes which could move the nation into the ranks of the world's larger exporters of oil and gas. One of the most promising regions is offshore Newfoundland and Nova Scotia, where full-cycle development has finally arrived following years of false starts. This article examines activity and prospects in some of the new oil and gas producing areas of Canada.

Will, G. 2000. Sable Island-a milestone for Canada's gas industry. Petroleum review. London. **54(638)**:36-37

Canada's natural gas industry recently took a major step in diversifying from its western base, with the start of production from the Sable offshore project. The delivery of gas in

late December 1999 set a milestone for the industry, as it marks the first time in over 20 years that a new natural gas supply basin in North America has been brought to market. This article reports on recent developments at the Sable Island project.

Wills, J. 1998. Impacts on Traditional Industries and Cultures: The Shetland Experience. Lessons from Frontier Regions, Proceedings. St. John's, Newfoundland.

Wilson, H. 1981. New Energy Policy, Jurisdictional Fuss Threaten Canada's Largest Offshore Field. Oil and Gas Journal. **79(15)**:83-89

Oil and gas production in Canada's Hibernia area and the effects of new federal energy policy are discussed.

A7 Tables and Charts

Table A-1
World Oil Supply and Demand
(Millions of Barrels per Day)

	1990	1991	1992	1993	1994	1995	1996	1997	1998*
World Oil Demand									
OCED									
Canada	1.69	1.63	1.63	1.68	1.72	1.87	1.71	1.80	1.80
US	16.30	16.00	16.26	16.47	16.95	16.96	17.47	17.74	17.95
Mexico	1.48	1.52	1.55	1.55	1.69	1.56	1.61	1.69	1.70
OCED Europe	13.60	13.60	13.70	13.70	13.80	14.10	14.30	14.40	14.60
Pacific	6.20	6.20	6.30	6.30	6.60	6.70	6.70	6.70	6.80
Non OCED	28.40	28.40	28.30	28.50	28.50	29.40	30.60	31.80	32.50
Total World Demand	**67.65**	**67.35**	**67.74**	**68.20**	**69.26**	**70.38**	**72.39**	**74.13**	**75.35**
World Oil Supply									
Non OCED	34.80	43.90	43.40	43.50	43.90	45.10	46.00	46.20	47.80
Call on OPEC	**23.85**	**23.45**	**24.33**	**24.7**	**25.36**	**25.28**	**26.39**	**27.92**	**27.55**

Table A-2
World Natural Gas Demand & Supply
Billion cubic metres per year

World Natural Gas Demand

	1990	1991	1992	1993	1994	1995	1996	1997
OECD								
North America - Canada	62	63	67	68	71	71	74	75
United States	540	549	564	583	596	621	632	633
Mexico	28	28	28	28	29	30	31	33
OECD Europe	249	264	264	281	282	304	338	336
Other OECD	107	111	112	116	126	131	146	150
Total OECD	986	1,015	1,034	1,076	1,104	1,157	1,221	1,226
Former Soviet Union	663	666	628	594	548	522	526	493
Rest of the World	316	320	341	362	385	416	453	478
Total World Demand	1,965	2,001	2,003	2,032	2,037	2,096	2,200	2,197

World Natural Gas Supply

	1990	1991	1992	1993	1994	1995	1996	1997
OECD								
Canada	99	105	116	126	136	148	154	157
United States	514	510	515	520	542	535	540	545
Other OECD	240	255	260	273	282	290	328	329
Total OECD	853	870	891	919	960	973	1,022	1,031
Former Soviet Union	760	756	729	710	671	660	669	623
Rest of World	374	395	414	436	458	497	537	569
Total World Supply	1,987	2,022	2,034	2,066	2,089	2,130	2,228	2,223

Tables A-1 and A-2
Source: Canadian Association of Petroleum Producers Foundation Paper, 1998

Figure A-1

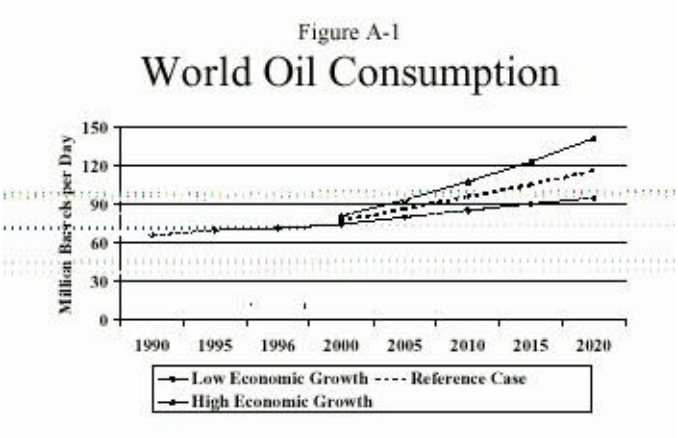
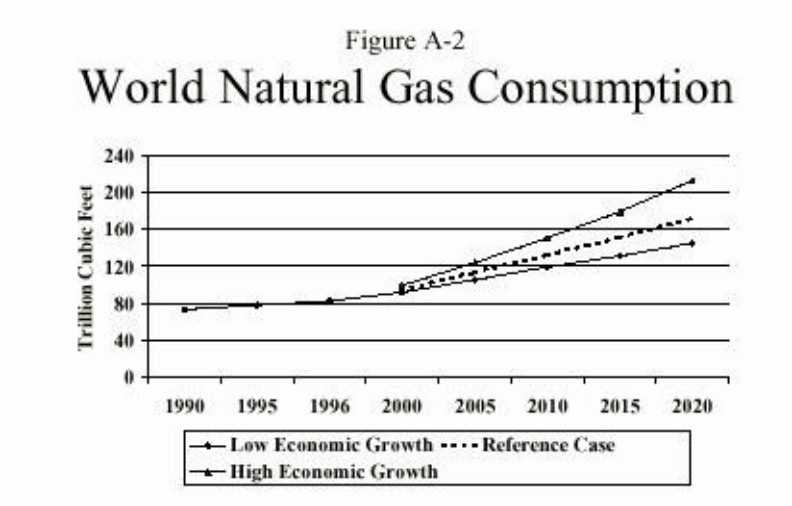


Figure A-2



Figures A-1, A-2
Source: McRae, R. N. 2000.