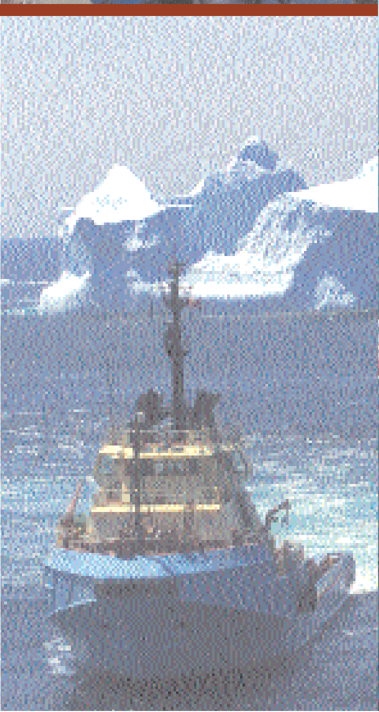
MARCH 2004

CANADA'S EVOLVING

Offshore Oil and Gas Industry



ENERGY

TODAY AND

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Key definitions

Hydrocarbons are compounds of hydrogen and carbon. The simplest hydrocarbon is methane (CH_4), composed of one carbon atom and four hydrogen atoms.

Natural gas is composed of mainly methane, although it often occurs in nature as a mixture with other hydrocarbons such as ethane, propane, butane and pentane and with other substances such as carbon dioxide, nitrogen, sulphur compounds and/or helium. These components are separated from the methane at processing plants located near the producing fields.

Crude oil is a naturally occurring liquid mixture of hydrocarbons. It typically includes complex hydrocarbon molecules – long chains and rings of hydrogen and carbon atoms. The liquid hydrocarbons may be mixed with natural gas, carbon dioxide, saltwater, sulphur compounds and sand. Most of these substances are separated from the liquid hydrocarbons at processing facilities near the producing field.

Petroleum is a general term for all the naturally occurring hydrocarbons – natural gas, natural gas liquids, crude oil and bitumen.

Natural gas liquids are composed of ethane, propane, butane and condensates (pentanes and heavier hydrocarbons) that are often found along with natural gas; some of these hydrocarbons are liquid only at low temperatures or under high pressure.

Liquefied natural gas (LNG): is supercooled natural gas that is maintained as a liquid at -160° C. LNG occupies 1/640th of its original volume and is therefore easier to transport if pipelines cannot be used.

Cubic metre: A cubic metre is 1,000 litres or roughly the volume occupied by a large office desk – equivalent to 6.3 U.S. barrels or 35.3 cubic feet. Canada currently produces about 375,000 cubic metres of crude oil and natural gas liquids per day and 490 million cubic metres of natural gas per day. Although Canada adopted the metric system in the 1970s, U.S. measurements (barrel for crude oil, thousand cubic feet for natural gas) are often used by industry and the news media. A convenient conversion tool is available on-line at http://www.convert-me.com/en/

Canada's Evolving Offshore Oil and Gas Industry

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Writer: Robert Bott

Photo courtesy of Husky Energy.

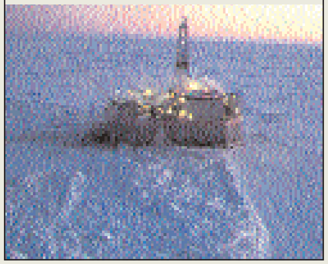


Photo courtesy of Imperial Oil Limited.

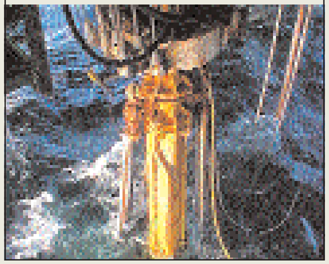


Photo courtesy of Ocean Rig.

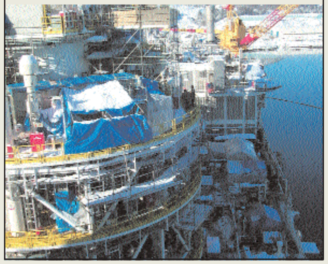


Photo courtesy of Newfoundland Ocean Industries Association.

Photo courtesy of Alex MacAulay/ Ocean Resources.

Photo courtesy of Alex MacAulay/ Ocean Resources.

1 Energy beneath the sea

What is Canada's offshore crude oil and natural gas industry?

Large amounts of crude oil and natural gas are located in sedimentary basins beneath the ocean's floor off Canada's shores. Developing these resources has given birth to a rapidly evolving industry employing thousands of Canadians. The industry has developed specialized skills and equipment and new approaches to worker training, safety management, government-industry collaboration, public consultation, environmental protection, and scientific research.

To date, Canada's offshore industry has focused primarily on the East Coast due to a wealth of resources located near energy-hungry markets, but Atlantic Canada is not the only region with offshore petroleum potential, nor the only beneficiary of development. This industry also provides jobs, creates new businesses and sparks the development of new technologies in other areas of the country.

On the West Coast, the British Columbia and federal governments are consulting stakeholders in preparation for the possibility of renewed offshore petroleum exploration and potential development. B.C. offshore exploration began in 1958 but was halted in 1972 after 14 wells had been drilled in geologically promising areas. The main reason for the governments' moratoria was their concern about a then-proposed (and never-used) route for Alaskan crude oil tankers through Canadian waters.

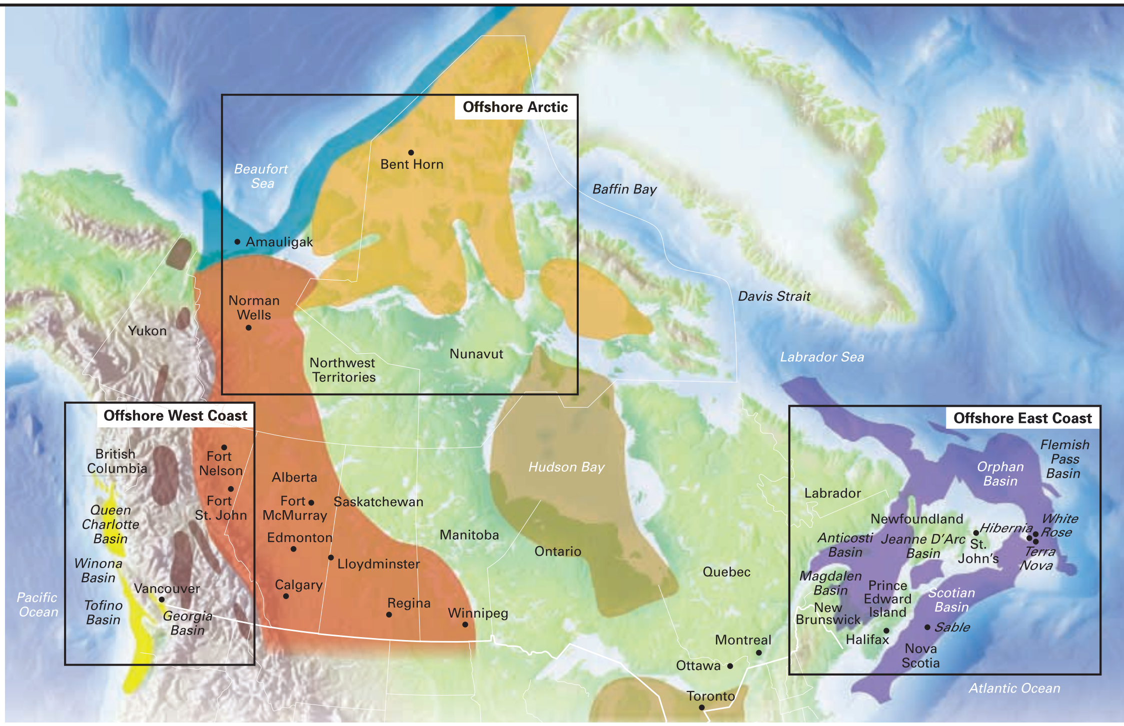
opportunity

Extensive onshore and offshore exploration in the Northwest Territories and Nunavut from the 1960s to the 1980s found substantial crude oil and natural gas reserves, and further development there awaits construction of pipelines to carry the resources to market. Amauligak, an oilfield under the Beaufort Sea, was one of the largest crude oil discoveries in North America in the last three decades. Nunavut has been estimated to contain as much as 10 per cent of Canada's conventional crude oil resources and nearly one-quarter of our natural gas resources.

The oil and gas industry has invested billions of dollars in seismic surveys and drilling to explore the petroleum potential off Canada's coasts. Additional billions have been spent for production and transportation facilities in Atlantic Canada. And the hunt continues. In 2003, for example, companies committed to spend $672.7 million exploring additional prospects off Newfoundland and Labrador during the next five to nine years. Industry experts also expect renewed drilling in Arctic waters within the next few years, and a new seismic survey was conducted in the Beaufort Sea in 2002.

Previous activity has resulted in three major crude oil production projects off Newfoundland and Labrador – Hibernia, Terra Nova and White Rose – and the Sable Offshore Energy Project producing natural gas off Nova Scotia. Nova Scotia was also home to Canada's first offshore development, Cohasset-Panuke, which produced crude oil from 1992 to 1999. Together, these projects represent an investment of more than $15 billion.

Why the high level of activity in the offshore? The answer can be found in this comparison: The average onshore well in Western Canada produces less than eight cubic metres of crude oil per day, but more than 9,000 cubic metres of crude oil per



Canada's seven hydrocarbon regions

Region	*Percentage of Canada's estimated conventional hydrocarbon resources*
Western Canada Sedimentary Basin*	57%
Atlantic Margin	18%
Arctic Cratonic	10%
Arctic Margin	6%
Pacific Margin	4%
Intermontane	3%
Eastern Cratonic	2%

** Excluding oilsands bitumen*

NOTE: These estimates were prepared by the Geological Survey of Canada to indicate the ultimate geological potential of sedimentary regions. They are useful to indicate the order of magnitude of various regions' resources, but are not the same as reserves that have been determined by actual drilling and can be produced economically. In some areas, such as the Western Canada Sedimentary Basin, a significant proportion of reserves have already been produced, but most of the resources remain in place. Also note that the estimates do not include the vast bitumen resources in the Alberta oilsands. Bitumen is a semisolid form of petroleum, dense and resistant to flow.

Source: Geological Survey of Canada.

Maintenance worker aboard the Rowan Gorilla V. *Photo courtesy of Alex MacAulay/Ocean Resources.*

The Atlantic Canada Advantage

- Large pool sizes
- Significant reserve potential
- Growing base of infrastructure
- Improving offshore technology
- Superior flow rates
- Large areas with hydrocarbon potential
- Geographic proximity to North America and Europe
- Marine heritage

Source: Newfoundland Ocean Industries Association.

day flowed initially from the first Hibernia well. The 24th oil-producing well drilled from the Hibernia platform, completed in 2004, flowed more than 6,000 cubic metres per day. Although the wells' output will decline over time, their production is still many times greater than the typical onshore well.

Why is the offshore crude oil and natural gas industry important to Canada?

- *Billions of dollars are pumped into the Canadian economy through capital spending and employment by the offshore crude oil and natural gas industry.*
- *The export of crude oil and natural gas has a positive impact on Canada's balance of trade, which helps offset the country's spending on imported goods and services.*
- *Profits earned by companies, and the expertise gained by their employees and contractors, help to make Canadians leaders in the international petroleum industry.*
- *Governments benefit from the royalties and taxes paid by the offshore industry.*

The offshore oil and gas industry pumps billions of dollars into the Canadian economy. This cash injection makes a significant contribution to the economic health of the country as well as individual provinces.

At the national level, the offshore industry has a positive impact on Canada's balance of trade – the difference between the amount of products imported and exported by a country – and improves the security of our energy supplies. Furthermore, the industry brings benefits to local economies, creates research and development opportunities, and raises the skill level of the workforce.

Crude oil and natural gas produced from the offshore developments offset the nation's use of imported oil, which is shipped into Eastern Canada by ocean tanker, mainly from South America and the Middle East, because it is cheaper than transporting crude oil by pipeline from Western Canada. About half of the imports come directly to Eastern Canadian ports; tankers deliver the remainder to Portland, Maine, for shipment by pipeline to Quebec and Ontario.

The majority of the crude oil produced off the East Coast is currently shipped to export markets in the United States and throughout the world. Likewise, most natural gas from the Sable Offshore Energy Project is shipped by pipeline to New England, but the project is also making this clean-burning fuel available for consumers and industries in the Maritimes. Greater use of domestic energy supplies, including by-product natural gas liquids such as propane, reduces the need for crude oil imports.

Because the Canadian people own the offshore oil and gas resources, governments receive revenues from the developments. The provincial governments of Newfoundland and Labrador and Nova Scotia collect royalties – the "owner's share" of production. Under legislated agreements called accords, between the federal government and the provinces of Nova Scotia and Newfoundland and Labrador, the royalties are set and collected by the provinces as if the wells were located on land. The provinces have created royalty policies based on both the wellhead value of the petroleum and the profitability of the individual projects. This approach allows the investor to recover much of the initial investment before paying an increasing share of revenues in royalties to the provinces.

Issungnak, site of several wells drilled in shallow waters of the Beaufort Sea during the 1970s and '80s. The wells were drilled from "sacrificial beach islands" created by dredging gravel and sand from the ocean floor. *Photo courtesy of Imperial Oil Limited.*

In addition, governments at all levels benefit from the property, sales, corporate and personal taxes paid by companies and employees. The industry helps to create thriving local economies and job opportunities.

What are the future prospects for offshore crude oil and natural gas development in Canada?

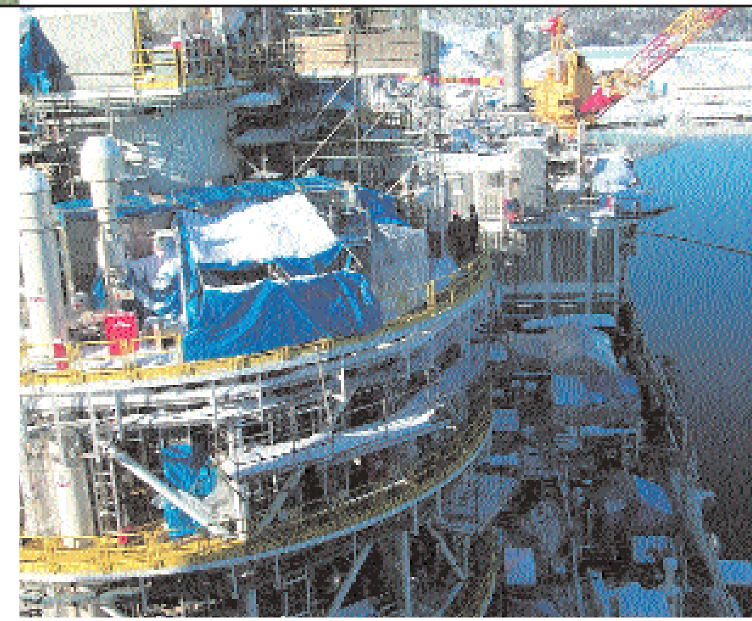
- *British Columbia is considering the possibility of renewed oil and gas exploration off the West Coast, and drilling could occur as early as 2010.*
- *Billions of dollars could be invested by 2020 to develop resources off the East Coast.*
- *Offshore crude oil and natural gas resources in the Canadian Arctic, discovered in the 1970s and 1980s, await the construction of transportation systems to markets in southern Canada, the United States and abroad.*
- *Arctic offshore exploration is expected to resume in the next few years.*
- *Today's offshore projects are creating the infrastructure and know-how needed for future developments.*

The four major production projects off the East Coast are the pioneers of Canada's offshore industry. Together, they are building the foundation for future offshore developments.

The projects have established an infrastructure of production and transportation facilities. They have also established a pool of talent and operating experience for the next generation of projects. That means future projects in Atlantic Canada may not have to be as large to be commercially viable, and they will be more economical to develop.

The creation of this foundation has prompted major companies in the area to expand their exploration activities, form alliances with key participants, and use state-of-the-art technologies to build portfolios of possible future projects. Governments are also gaining experience in how to regulate the petroleum industry effectively and efficiently and to reap economic rewards without unduly hampering industry expansion.

A study by the Newfoundland Offshore Industries Association in 1999 indicated that new petroleum development projects could begin in Atlantic Canada every two or three years over the next two decades. If this were to occur, as it has thus far, offshore crude oil production could provide more than one-fifth of Canada's output of crude oil and natural gas liquids – and more



The Terra Nova floating production, storage and offloading vessel during its commissioning in Bull Arm, Newfoundland, 2001. *Photo courtesy of Newfoundland Ocean Industries Association.*

The Terra Nova floating, production, storage and offloading vessel.
Photo courtesy of Petro-Canada.

The Hibernia platform in waters 80 metres deep on the Grand Banks.
Photo from HMDC.

than three times Atlantic Canada's current crude oil consumption. According to the study, as much as $24 billion (1999 dollars) could be invested to produce nearly $60-billion worth of resources.

Current projects on the East Coast are located in comparatively shallow water, less than 150 metres deep. Deepwater drilling, in waters more than 1,000 metres deep, is expected be a significant factor in the future of the oil and gas industry, in Canada and worldwide. Off Nova Scotia, in the region known as the Scotian Slope, deepwater wells are aiming for natural gas reserves three times larger than those discovered in shallower water on the Scotian Shelf. Three deepwater wells were drilled on the Scotian Slope by the end of 2002, and two more began drilling in 2003. Two deepwater wells were also drilled off Newfoundland and Labrador in 2003.

The pace of future development off the East Coast will depend on factors such as new discoveries, the regulatory environment, technological improvements and trends in crude oil and natural gas prices.

The time frame is less certain for other crude oil and natural gas resources off Canada's Arctic and Pacific coasts. Economical transportation facilities must be built before development will proceed in Arctic waters, but renewed exploration is anticipated in the next few years. Although exploration off Canada's West Coast has been halted since 1972 by the federal and provincial moratoria, geological studies indicate substantial petroleum resources may also exist there.

If petroleum is confirmed by drilling in a new exploration region, such as the West Coast, experience in Canada and elsewhere indicates that it can take 10 years or more before crude oil or natural gas begins flowing to market. The time lag is due to the need for a number of steps that must occur before production can begin:

- drilling additional wells to determine the extent and quality of the reservoir;
- establishing the framework for regulation and revenue sharing, if this is not already in place;
- consulting stakeholders who might be affected by exploration and development activities;
- environmental impact assessment and related scientific research;
- detailed economic and engineering studies;
- investor commitments and regulatory approvals;
- construction of production and transportation facilities.

However, experience gained from past operations in Atlantic Canada and other regions, coupled with a long-established onshore petroleum industry in Western Canada and a highly capable marine services sector in British Columbia, could contribute to a reduced time lag for development on the West Coast if renewed exploration is allowed and commercially viable reserves are discovered.

2 Sharing the benefits

How do local communities benefit from the offshore crude oil and natural gas industry?

- More than one-third of the billions spent by the offshore industry go directly into regional and local economies.
- The offshore industry creates thousands of jobs and spurs employment in businesses such as onshore support, training, transportation and marine services.
- New industries such as petrochemicals are attracted by the availability of offshore natural gas, natural gas liquids and crude oil.

Between one-third and two-thirds of the dollars spent on offshore exploration and development flow directly into regional and local economies in the form of wages, purchases of goods and services, and taxes.

Employment is one of the important contributions the offshore industry makes to local economies. The industry directly creates thousands of jobs in a wide variety of fields, from construction labour to high technology, and thousands more jobs are created indirectly to provide goods and services for the industry and its employees. The positive impact of offshore development – including the creation of more than 50,000 person-years of direct local employment – is already evident in Nova Scotia and Newfoundland and Labrador, where the industry has moved beyond pure exploration and now includes development and production.

development

Heliport pad with scramble net aboard the Rowan Gorilla V offshore Halifax, Nova Scotia.
Photo courtesy of Alex MacAulay/Ocean Resources.

A worker controls drilling equipment on the Hibernia platform.
Photo from HMDC.

Even more jobs are created by the industry's high demand for local goods and services. This can set off a chain reaction of spending and hiring across regional businesses. When all the effects are considered, the industry generates an additional three or four jobs for every direct job created. Colleges and universities throughout Atlantic Canada now offer industry-specific courses and training in skills and trades needed to support the offshore and onshore oil and gas industry.

Specialized supplies and services such as drilling fluids, pipe coating, weather forecasting, supply vessels and helicopters are needed to meet the technical, safety and environmental challenges of the offshore industry. This demand sparks local interest in new business ventures and careers. Industries such as petrochemicals are attracted by the availability of crude oil and natural gas and by products such as natural gas liquids.

Government revenue, in the form of taxes and royalties, goes to pay for services such as health and education that benefit all citizens.

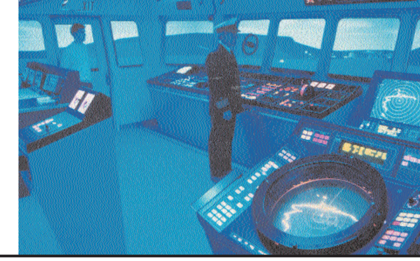
New Brunswick and Nova Scotia have also benefited from construction of the pipeline to transport natural gas from the Sable Offshore Energy Project to Canadian and U.S. markets. The growing availability of natural gas provides the region with a locally produced energy source. Now that a transportation system is in place, there has also been renewed interest in onshore, near-shore and offshore natural gas exploration in Prince Edward Island, New Brunswick, Nova Scotia and eastern Quebec. One small onshore field is already producing natural gas in New Brunswick.

The economic stimulus provided by the offshore industry is particularly important for regions affected by high unemployment in traditional industries such as fishing, forestry and coal mining. From 1966 to 2002, the oil and gas industry spent $15.9 billion in exploration and development off Newfoundland and Labrador's coast and more than $5 billion off the shores of Nova Scotia. This spending included:

- $5.8 billion to build the Hibernia project, of which $2.8 billion was spent in Newfoundland and Labrador;
- $768 million spent in Newfoundland and Labrador during the pre-production phase of the $2.8-billion Terra Nova development, and approximately $330 million in operating expenditures from startup in 2002 through early 2004;
- $2.35 billion developing the White Rose production facilities;
- $1.5 billion developing and operating the Cohasset-Panuke project;
- $2 billion developing the Sable Offshore Energy Project plus $1 billion for associated pipeline construction.

All of these projects have made an important economic contribution to communities throughout the Atlantic region. The Hibernia oil development is the largest single project to date. Naturally, it has had the most significant impact. Residents of Newfoundland and Labrador provided 66 per cent of the 63 million person-hours of labour needed to build the massive production system. In operation, Hibernia directly employs about 875 people, of whom about 89 per cent come from Newfoundland and Labrador.

The construction of other projects has not been as labour-intensive as Hibernia. However, Nova Scotians have accounted for 54 per cent of the labour and materials expenditure for the Sable Offshore Energy Project. Annual operating expenditures



The Marine Institute's Full Mission Bridge Simulator consists of a real size ship bridge mounted on a moving platform surrounded by a 360-degree visual screen. *Photo courtesy of the Marine Institute.*

The Marine Institute's Navigation and Blind Pilotage Simulator trains mariners to navigate a vessel safely in restricted visibility with the use of instruments only. *Photo courtesy of the Marine Institute.*

for the Sable Offshore Energy Project are between $100 million and $200 million.

In its production operations, Terra Nova employs 985 people, directly and on contracts (onshore and offshore), about 84 per cent of whom are from Newfoundland and Labrador. During the peak pre-production phase of the Terra Nova development, 2,000 people were employed, and about 29 per cent of total expenditures were in Newfoundland and Labrador. During pre-production, White Rose employs 1,900 people, and about 33 per cent of project expenditures are in Newfoundland and Labrador.

Workers and businesses that fill the offshore industry's needs also try to develop skills and products that can compete in the international marketplace. Local companies and workers that were involved in oil and gas exploration off the East Coast during the 1980s found ready markets for their services in Indonesia and other foreign countries when a slowdown occurred in the Canadian industry in the late 1980s and early 1990s. These companies and workers brought back additional skills when they returned to Atlantic Canada as the pace of development picked up later in the 1990s.

Companies and their employees make significant contributions to charitable, educational and recreational organizations in local communities. Regional economies also benefit when specialized workers and equipment must be brought in from other parts of the country to fill gaps in the local industry. These workers help the industry strengthen its capabilities, and they contribute to local economies through purchases of goods such as homes and vehicles and the payment of taxes to local governments.

What are the scientific and technical benefits of the offshore industry?

- *New technologies have been developed to avoid collisions between offshore facilities and icebergs.*
- *Exploration off the East Coast has created a substantial body of oceanographic information.*

The activities of the offshore industry have spurred research and development in a wide variety of areas.

To operate in the iceberg-prone waters off Newfoundland and Labrador, the industry has developed many new technologies to monitor ice movement and avoid collisions.

Companies use sophisticated over-the-horizon radar that can detect icebergs more than 40 kilometres away. Techniques have been developed that allow powerful 80-metre-long supply vessels to divert an iceberg from a collision course with a production platform. In some instances, supply vessels can lasso an iceberg and steer it away from production facilities. Another technology uses high-pressure water jets to steer smaller icebergs onto a safer course.

To develop new procedures and materials for operating in one of the world's most challenging environments, the Centre for Cold Ocean Resources Engineering (C-CORE) in St. John's leads a Harsh Environment Initiative. C-CORE is applying harsh-environment technologies drawn from space research to operations such as those on the Grand Banks off Newfoundland and Labrador, and is contributing results of its own harsh-environment research to the European Space Agency. One innovation from the program is high-intensity lighting to assist helicopter landings on the Hibernia platform.

Workers handling a drill pipe.
Photo from HMDC.

As part of Hibernia's ice management strategy, encroaching icebergs are "lassoed" with a heavy cable and towed by a support vessel into a different trajectory.
Photo from HMDC.

The offshore petroleum industry has made a major contribution to our knowledge of the seas and resources off Canada's coasts. For example, about $511 million was spent on exploration off the Labrador coast between 1973 and 1983. It may be decades before any of the area's natural gas discoveries are developed. However, this work has established a substantial body of oceanographic and geological knowledge about the area, and new technologies may soon make it possible to develop Labrador offshore natural gas. Since 1958, the oil and gas industry has made similar contributions to scientific knowledge of the Arctic and West Coast offshore areas, such as assisting in the identification of sensitive and unique biophysical features.

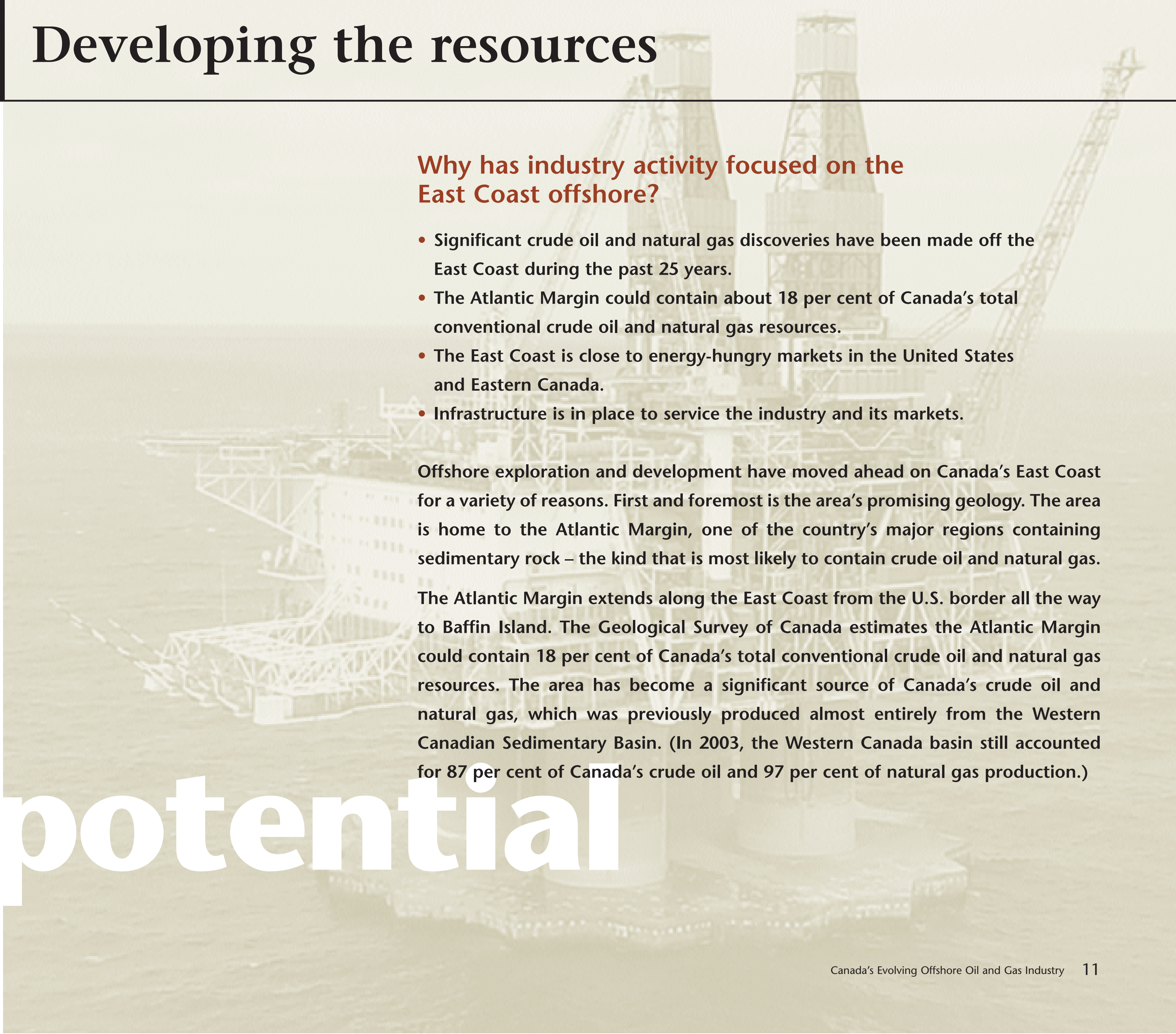
Other areas of ongoing research include: environmental protection, occupational health and safety, subsea mapping, satellite navigation systems, marine biology and many other fields. On the East Coast, a public-private non-profit partnership, Petroleum Research Atlantic Canada, was established in 2002 as a means of building petroleum-related research and development capability and capacity throughout the region. In addition, the Environmental Studies Research Funds (ESRF) finances environmental and social studies pertaining to exploration, development and production activities on Canada's frontier lands, including the offshore. The funds have supported more than $15 million of research since 1993, including studies of the impact of seismic programs on fisheries off the East Coast.

Oil and gas-related training programs available in Canada

- Pre-employment Floorhand Training
- Petroleum Engineering Technology Diploma
- Well Control Certification
- Basic Survival Training
- Cartography
- Geographic Information Systems
- Global Positioning Systems
- Right-of-Way Surveys
- Occupational Health and Safety
- Remote Sensing
- Exploration Technology
- Geomatics Engineering Technology
- Offshore Operations
- Process Operations
- Marine Navigation (Ship Masters Training)
- Hydrography and Marine Surveying
- Engineering
- Earth Sciences
- Computer Assisted Design/Computer Assisted Manufacturing (CAD/CAM)
- ISIS – Intelligent Sensing for Innovative Structures
- ACMBS – Advanced Composite Materials in Bridges and Structures
- Environmental Science
- Ex Training (specialized training in electrical apparatus in hazardous and potentially explosive areas)
- Masters in Oil and Gas (executive training)
- Geology
- Geophysics
- Surveying

To learn more about careers in the oil and gas industry, visit www.centreforenergy.com

3 Developing the resources



Why has industry activity focused on the East Coast offshore?

- Significant crude oil and natural gas discoveries have been made off the East Coast during the past 25 years.
- The Atlantic Margin could contain about 18 per cent of Canada's total conventional crude oil and natural gas resources.
- The East Coast is close to energy-hungry markets in the United States and Eastern Canada.
- Infrastructure is in place to service the industry and its markets.

Offshore exploration and development have moved ahead on Canada's East Coast for a variety of reasons. First and foremost is the area's promising geology. The area is home to the Atlantic Margin, one of the country's major regions containing sedimentary rock – the kind that is most likely to contain crude oil and natural gas.

The Atlantic Margin extends along the East Coast from the U.S. border all the way to Baffin Island. The Geological Survey of Canada estimates the Atlantic Margin could contain 18 per cent of Canada's total conventional crude oil and natural gas resources. The area has become a significant source of Canada's crude oil and natural gas, which was previously produced almost entirely from the Western Canadian Sedimentary Basin. (In 2003, the Western Canada basin still accounted for 87 per cent of Canada's crude oil and 97 per cent of natural gas production.)

From keel to helideck, the Terra Nova floating production, storage and offloading vessel stands more than 18 stories high. The vessel is a ship-shaped production platform with integrated oil storage from which oil is offloaded to a shuttle tanker.
Photo courtesy of Newfoundland Ocean Industries Association.

East Coast Sedimentary Basins and Production Projects

Gas Fields

Oil Fields *Source: Government of Newfoundland and Labrador .*

Producing crude oil and natural gas from the East Coast makes economic sense because it is close to energy-hungry markets in heavily populated areas such as the northeastern United States and Central Canada. U.S. demand for Canadian crude oil and natural gas has increased steadily over the past 15 years. As a result, Canada now fills 18 per cent of U.S. natural gas requirements.

East Coast crude oil has ready markets in Eastern Canada, the United States and abroad. Ontario, Quebec and Atlantic Canada otherwise rely on crude oil imported from abroad because it is cheaper than transporting crude oil by pipeline from Western Canada. In 2003, Canada imported about 140,000 cubic metres per day of crude oil, but exported about 225,000 cubic metres per day, mainly to the United States.

Local governments and communities in Atlantic Canada actively supported development of a crude oil and natural gas industry. This positive environment, combined with large reserves and accessible markets, made the East Coast an attractive location for Canada's offshore industry. The industry concluded the area provided a better investment opportunity than many other locations throughout the world.

The number of major oil and gas discoveries made off the East Coast supported this view. A major crude oil discovery is defined as greater than 16 million cubic metres of recoverable reserves. Between 1978 and 1998, there were only 11 of these very large oil discoveries in North America. And four of those discoveries – including the largest, Hibernia – occurred off the coast of Newfoundland and Labrador, in the Grand Banks region. The four discoveries were:

(*Estimated Reserves)	Crude Oil	Natural Gas	Natural Gas Liquids
	million cubic metres	billion cubic metres	million cubic metres
1979 – Hibernia	137.6	37.2	25.5
1981 – Hebron	51.6	–	–
1984 – Terra Nova	64.4	7.6	2.2
1984 – White Rose	45.0	76.7	15.3

**Source: Canada – Newfoundland Offshore Petroleum Board 2002-03 Annual Report.*

Long Beach, Pacific Rim National Park, Vancouver Island. *Photo courtesy of Tourism B.C.*

Canada's fifth major crude oil discovery in this era also occurred in 1984 when drillers hit the Amauligak field in the Beaufort Sea, off the Arctic shore. Its estimated reserves are more than 48 million cubic metres of crude oil and 65 billion cubic metres of natural gas. Of the 11 major North American discoveries, the remaining six occurred in the United States, largely in the Gulf of Mexico.

In total, there were 23 discoveries classified as "significant" – capable of sustained crude oil or natural gas production – on the Grand Banks off Newfoundland and Labrador by the end of 2003. Off Nova Scotia, there were a total of 22 significant discoveries reported by the end of 2003. The Nova Scotia offshore discoveries include two of crude oil, two with combined crude oil and natural gas, as well as a total of 18 natural gas discoveries. Nova Scotia's offshore area contains one of four major natural gas basins in North America to be developed in recent times. The other three are located in Western Canada, central United States and the Gulf of Mexico.

Natural gas being produced off Newfoundland and Labrador is currently re-injected into the reservoirs to enhance crude oil production. However, as the fields mature and new resources are discovered, it is likely that the natural gas will also be produced commercially and shipped to markets by pipelines or by tankers carrying liquefied or compressed natural gas.

What is the potential off the West Coast?

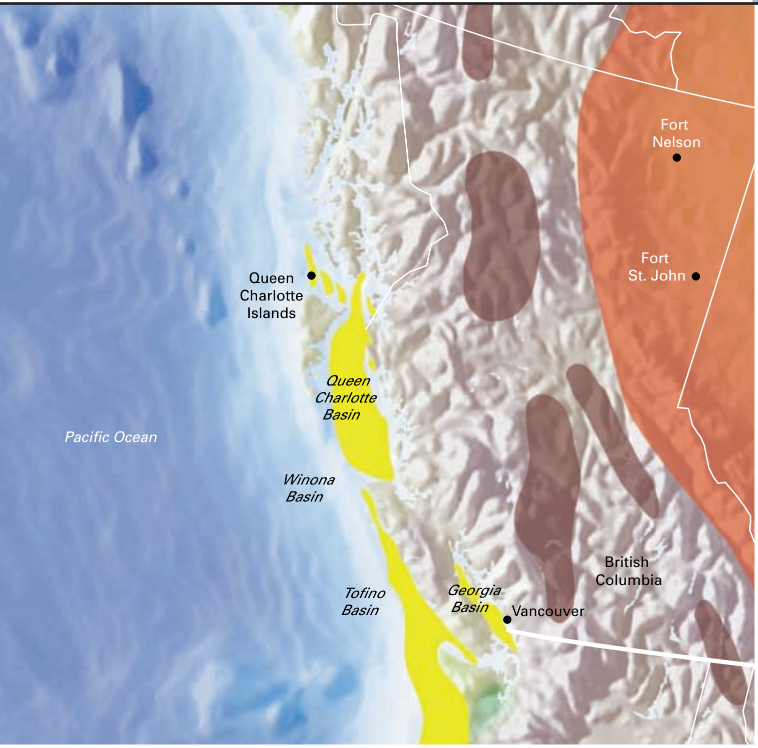
In 1972, the federal and provincial governments decided to halt oil and gas activity off British Columbia's coast, mainly because of concerns about proposed Alaskan oil tanker traffic. Before the governments imposed the moratoria, 14 offshore wells had been drilled. The wells encountered natural gas off the Vancouver Island port of Tofino and non-commercial quantities of crude oil off the Queen Charlotte Islands

According to the Geological Survey of Canada, the Queen Charlotte Basin could contain up to 734 billion cubic metres of natural gas and 1.56 billion cubic metres of crude oil. Three other areas of sedimentary rocks off the B.C. coast have smaller potential resources, primarily natural gas. The entire Pacific Margin region is estimated to contain about 4 per cent of Canada's total conventional hydrocarbon resources.

The economy of coastal British Columbia has historically relied heavily on the fishing and forestry industries. Downturns in both of those industries led in part to a renewed interest by the provincial government and coastal communities in removing the existing moratoria and enabling renewed exploration and potential development. While the resource potential is considerable, the B.C. government stated that it is committed to ensuring that exploration and development occur only if they can be demonstrated to be environmentally responsible and that coastal communities benefit. Scientific and technical reviews conducted for the province as recently as 2002 concluded that although there are some information gaps, there are no scientific or technical barriers to offshore exploration and development. Concurrently, the provincial government gathered initial community feedback that

Sedco 135-F, the first offshore drilling vessel constructed in Canada, was commissioned in a dockside ceremony in Victoria in 1967. The semi-submersible platform cost $10 million to construct and was capable of drilling to depths of 3,700 metres. *Photo courtesy of Shell Canada Limited.*

Despite recent downturns, fishing remains a vital part of coastal economies and lifestyles. Federal and provincial authorities are assessing possible effects that renewed West Coast exploration might have on fisheries.
Photo by Armstrong Creative.



West Coast Sedimentary Basins

Source: Government of British Columbia.

identified the need for more information on the risks and benefits of offshore oil and gas activity. To move the issue forward, the province established a team of senior officials focused on filling information gaps, developing a fiscal and regulatory framework and working with First Nations, communities and stakeholder groups.

The federal government meanwhile commissioned a scientific report by an expert panel of the Royal Society of Canada, which submitted its report in 2004, and established a public review panel to examine other issues such as environmental impacts, protected areas and economic issues. The Royal Society noted that a number of key scientific issues such as at-risk species and habitats, sea-floor stability, currents, tides, waves, earthquake risk and oil-spill potential would need to be addressed. “If the moratoria were lifted,” the report stated, “regulation would be in place to ensure that these critical science gaps would be filled before development of an oil and gas industry in the QCB [Queen Charlotte Basin]. We also note that lifting the moratoria would enhance the opportunities for filling many of the science gaps, through shared-cost partnerships involving industry participation.” The Royal Society report also recommended continuing the present restrictions on tanker traffic along the West Coast.

In addition to the public review panel, the federal government also began a parallel consultation with First Nations. “The overall goal of [the public] review is to provide decision makers with a solid understanding of the possible impacts of oil and gas activities in selected B.C. offshore areas,” the federal minister stated. “The approach will be comprehensive, balanced and co-operative so that informed decisions can be based on information that reflects the views of all stakeholders.” Both federal consultation processes were continuing in 2004 as this booklet went to press.

As in the East Coast and the Arctic, all industry activity off the West Coast would be subject to detailed environmental assessment and regulatory approval.

In the 1970s and 1980, a number of Beaufort Sea exploration wells were drilled in shallow water from a caisson-retained island. *Photo courtesy of Imperial Oil Limited.*

What is the potential in the Arctic?

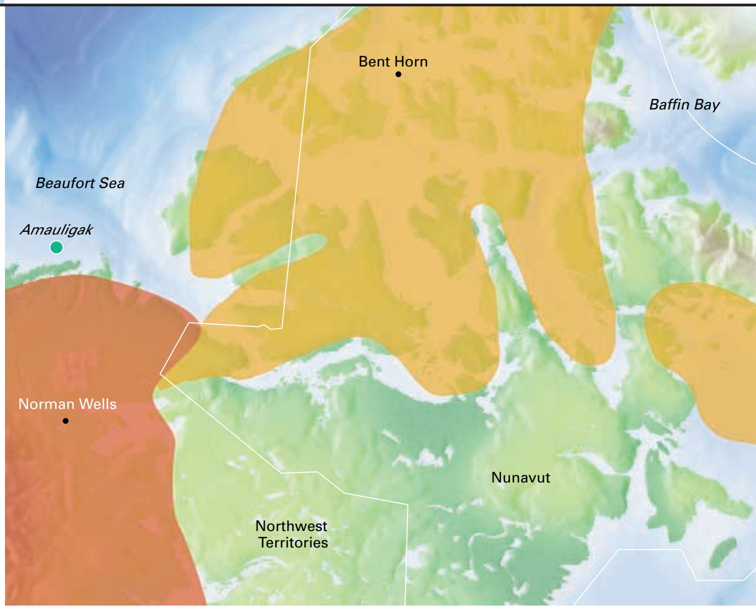
The Geological Survey of Canada has estimated that two Arctic sedimentary regions, the Arctic Cratonic and Arctic Margin, contain about 16 per cent of Canada's total conventional hydrocarbon resources. Substantial portions of these resources are located offshore in the Beaufort Sea and among the Arctic Islands. Extensive exploration from the 1960s to the 1980s confirmed reserves in these areas, including the major Amauligak oil and gas field in the Beaufort Sea.

However, the development of Arctic petroleum resources has been delayed for many years by the high cost, complex regulatory environment, Aboriginal issues, short seasons, and environmental issues involved in building production and transportation systems to distant markets. Higher crude oil and natural gas prices, and dwindling supplies elsewhere in North America, have renewed interest in the region's onshore and offshore potential. A natural gas pipeline has been proposed from the Mackenzie Delta to southern markets, and several companies have indicated interest in renewed offshore exploration.

The major exception is the Norman Wells oilfield in the Northwest Territories, which has been producing since the 1920s. It differs from other frontier operations because it is part of the Western Canada Sedimentary Basin and is connected by a pipeline to Alberta and other markets. A feature of Norman Wells is the use of directionally drilled wells and artificial islands in the Mackenzie River to reach the large part of the reservoir located under the river.

The first modern frontier production was crude oil from the Bent Horn well in the Arctic Islands. From 1985 to 1996, tankers carried crude oil from Bent Horn to East Coast ports during the short summer shipping season. Except for seasonal tanker shipments such as those from Bent Horn, no major crude oil or natural gas production is expected from the Arctic until a pipeline is built from the Mackenzie Delta to southern Canada.

Experience gained at Norman Wells and Bent Horn, plus developments in other Arctic and offshore regions around the world, indicates that the resources can eventually be produced safely and economically with minimal environmental impacts. The industry conducted numerous research and development projects in the 1970s when it appeared that a natural gas pipeline project was imminent.



Arctic Sedimentary Basins and Production Project

Oil Field *Source: Geological Survey of Canada.*

4 Environment and stakeholders

How is the environment protected during offshore exploration and production?

- No offshore activity can occur without an environmental assessment and regulatory approval.
- Geophysical vessels gradually increase sound levels at the beginning of seismic surveys so fish and mammals can move away from the immediate area.
- The industry uses specialized equipment to reduce the possibility of spills during drilling.
- Offshore facilities are designed for the particular environment where they will be located.
- Low-toxicity drilling fluids are used, and rock cuttings are separated from the fluid before they are disposed at sea.
- Double-hulled and double-bottomed tankers are used to transport crude oil from production facilities.
- Company and government officials continually monitor environmental impacts.
- Restrictions are in place to protect sensitive marine environments.
- Companies work with the Coast Guard, spill-response organizations and other government agencies to prevent spills and prepare for fast and effective response if they occur.
- Sophisticated risk-management methods are used to identify appropriate protective measures.

protection

Environmental protection is an important consideration in all offshore exploration and development projects. Projects are designed and operated to minimize their impact on water and air quality, aquatic species and other aspects of the environment in which they operate.

Detailed environmental protection plans are tailored to the particular issues of each offshore operation. Government agencies review and approve the plans and then monitor activities to make sure the plans are put into effect.

The industry has developed specialized equipment and products that reduce its impact on marine ecosystems. Heavy-duty blowout preventers are used to reduce the possibility of releases into the environment during drilling. Water-based drilling fluids are used wherever possible. If water-based fluids would damage rock formations, a low-toxicity synthetic oil is used. Rock cuttings from drilling with oil-based fluids are either reinjected into wells or are separated from the fluid before they are disposed at sea. Other wastes are taken ashore by service vessels for disposal. Drains and holding tanks are used to contain leaks and spills during normal operations on the platforms.

Facilities are designed for the environments in which they work. The Terra Nova floating production, storage and offloading facility is double-hulled and ice-strengthened, and it can be disconnected from the producing equipment if necessary. The White Rose production system includes similar features. The Hibernia platform is designed with an ice barrier to withstand the impact of an iceberg.

However, not all the waters off Atlantic Canada are iceberg prone. The areas off the east coast of Newfoundland and off the coast of Labrador are subject to iceberg traffic to varying degrees, and the traffic off Labrador is a much greater concern. Other areas, such as off the south coast of Newfoundland and east and south of Nova Scotia, are usually ice free. The Gulf of St. Lawrence is subject to pack ice but has a very low iceberg risk. So the environmental challenges vary in the offshore areas and demand different kinds of exploration and development strategies.

Double-hulled and double-bottomed tankers that are specially reinforced to handle ice are used to carry crude oil from Grand Banks production facilities off Newfoundland and Labrador. Although the Cohasset-Panuke project was in ice-free waters, it used one double-hulled and one double-hulled and double-bottomed tanker for transportation and storage of its product.

All offshore facilities maintain their own onboard spill-response teams and equipment. Companies devote considerable resources towards preventing spills through the design of facilities and operating procedures, and personnel are trained to respond quickly and effectively if a spill occurs. Emergency response exercises, conducted with the Canadian Coast Guard and Eastern Canada Response Corporation, are a regular part of the facilities' operations.

Eastern Canada Response, an industry-funded spill response organization, also maintains equipment and trained crews in Dartmouth, Nova Scotia, and St. John's, Newfoundland and Labrador, to respond in the event of an oil spill, and co-operates with other national and international spill-response organizations.

Orca whales off the West Coast.
Photo courtesy of Tourism B.C.

The Hibernia platform is located on the Grand Banks, 315 km east southeast of St. John's, Newfoundland.
Photo courtesy of Chevron Resources-HMDC.

Steps in Emergency Prevention Planning

1 Identify site-specific safety/environmental hazards.

2 Plan operations and design equipment to eliminate/ reduce those hazards.

3 Ensure workers understand equipment and know how to recognize and react to problems.

4 Continuously monitor and fix equipment before it fails and use fail-safe monitors, alarms and automatic shutdowns as a back-up program.

5 Make sure there is enough extra equipment and trained people on site to respond to an emergency.

6 Review any emergency event to prevent recurrence.

Source: Canadian Association of Petroleum Producers.

Company and government officials monitor environmental impacts continually. The Environmental Studies Research Fund was established in 1983 and uses levies on petroleum interests to fund environmental research related to offshore and frontier petroleum activities. A board composed of industry, government and public representatives administers the fund, which currently spends more than $1 million annually.

There are essentially two ways to deal with offshore emergencies. The best way is to prevent incidents from happening at all. But if they do occur, industry must be ready to respond quickly and effectively. From the earliest stages of planning to the end of oil and gas production (generally about 20 to 30 years later), offshore companies take numerous precautions to minimize the chance of an incident. Still, there are no guarantees. Companies thus have extensive plans, procedures and training programs in place to deal promptly and effectively with any emergencies that might occur.

Companies prepare for such incidents as injuries to workers, oil spills, blowouts, fires and explosions, and vessel collisions. Emergency plans also include the possibility of ice damaging drilling and production equipment, vessels or pipelines, although such incidents occur very infrequently.

When an offshore oil and gas project is first proposed, planners must identify and analyze potential risks to people and the environment. This process includes taking steps to reduce or eliminate identified hazards, training workers to recognize and respond to potential emergencies, and monitoring and repairing equipment before failures occur.

All offshore oil and gas operations in Canada are required by law to have comprehensive emergency response plans and procedures in place before the relevant regulator approves their activities. These regulated activities range from seismic surveys, drilling, and production operations to facility construction. They also include transportation of oil and gas by shuttle tanker or pipeline.

Blowouts can occur when crude oil and/or natural gas under pressure escapes from a well into the environment. They are extremely rare and are generally brought under control within a week. There have been only two blowouts since offshore drilling began in Atlantic Canada in the 1960s. Subsequent studies showed the blowouts had no long-term effects on the environment, although one of them released 238,500 litres of condensate (very light oil) in 1984 before it was brought under control. Other spills can occur when known volumes of liquids escape during cargo transfers, or when there are pipeline or equipment failures on a drilling rig or production platform. Most spills from offshore operations in Atlantic Canada have released less than 160 litres of liquids.

All spills must be reported to regulatory authorities. Of the 77 spills recorded by the Canada-Newfoundland Offshore Petroleum Board in the four-year period from 2000 through 2003, only 19 were greater than 10 litres. Of the 13 spills greater than 150 litres, the largest was 23,700 litres of low-toxicity synthetic drilling fluid. The major component of this fluid is a food-grade synthetic oil similar to "baby oil."

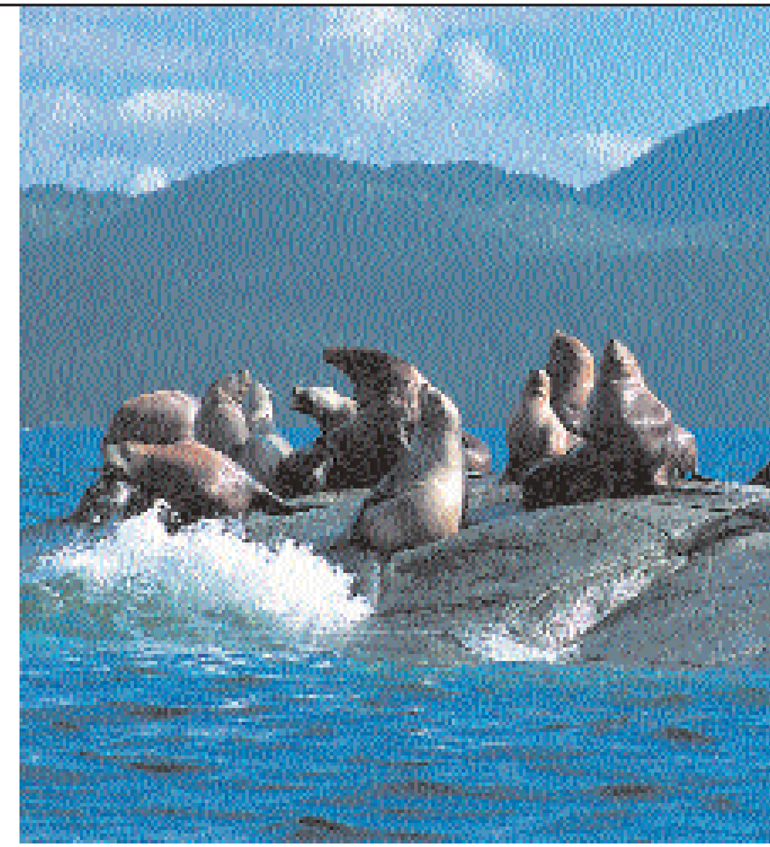
Of the 61 spills recorded by the Canada-Nova Scotia Offshore Petroleum Board between 2000 and 2003, only 12 were greater than 10 litres and of these just four were greater than 150 litres. The largest of these was 7,290 litres of conduit fluid – a mixture of ethylene glycol, lubricant and freshwater – which disperses quickly and is considered non-toxic in the marine environment. Eleven of the 18 spills recorded off Nova Scotia in 2003 involved small releases of kerosene by a seismic vessel that was called back into port for additional inspection and measures to prevent further such releases.

Companies have extensive plans for responding to oil spills. After ensuring no people are at risk, support vessels move quickly to contain the oil using special booms. Then skimmers or special absorbent materials are deployed to recover crude oil from the sea surface. While mechanical recovery is preferred, oil on water is very difficult to contain, particularly in bad weather. Sometimes the most effective option is to closely monitor the spill's movement and allow evaporation, wind, wave action and bacteria to naturally disperse and break down the oil. Occasionally, companies will use other methods such as igniting the oil or spraying chemicals to disperse it in the ocean, but only after governments have approved such action.

Offshore emergency response plans identify sensitive habitats, sea birds, mammals and fish resources that could be affected by a spill. This process involves assessing the characteristics of oil that might be spilled – heavier oils do not evaporate as readily as lighter crudes – and the speed at which spilled oil could move into sensitive biological areas. Coastal areas are particularly sensitive to the effects of oil spills. Companies have developed procedures to gain access quickly to equipment and trained personnel able to contain and clean up spills in these areas.

The fishing industry is concerned that potential spills can result in temporary loss of access to fishing grounds and damage to fishing vessels and gear. If this happens, offshore operators have established programs to compensate fishermen who suffer financially from a spill. The fishing industry is also concerned about spills causing potential contamination of species. In response, offshore operators have plans in place to sample fish near a spill site to determine fish quality and identify areas where fish have been exposed to oil and become tainted.

The federal government has stepped in to safeguard valuable marine habitats such as The Gully and Georges Bank. The Gully is a deep underwater canyon located east of Sable Island, off Nova Scotia. After five years of study and consultation, the government announced in 2003 the final stage of public consultation prior to officially designating The Gully a marine protected area. The proposed protected area is 2,364 square kilometres and encompasses important areas for deep-sea corals, fish and a variety of dolphin and whale species, including the at-risk Scotian Shelf population of northern bottlenose whales. The Department of Fisheries and Oceans is working with Parks Canada to create a network of marine protected areas off Canada's coasts, including one proposed in a portion of the Beaufort Sea.



Sea lions off the West Coast. *Photo courtesy of Tourism B.C.*

Lifesaving capsules aboard the Rowan Gorilla V jackup platform. *Photo courtesy of Alex MacAulay/Ocean Resources.*

In 1988, the federal and Nova Scotia governments imposed a 12-year moratorium on exploration and drilling on Georges Bank, an area of sand-bottomed shallows located between southern Nova Scotia and New England. Following public hearings, a review board recommended a 10-year extension of the moratorium in 1999, and the governments agreed to do so in 2000. The United States also has imposed a moratorium on exploration in its portion of Georges Bank, effective until 2012.

The Royal Society of Canada has recommended the creation of coastal exclusion zones to protect sensitive marine environments such as sponge reefs off the West Coast. In 1988, a federal-provincial agreement was signed to establish Gwaii Haanas (Place of Wonder) National Marine Conservation Area Reserve. The proposed conservation area extends about 10 kilometres offshore, encompassing approximately 3,400 square kilometres of the Hecate Strait and Queen Charlotte Shelf marine regions. In support of the proposal, four companies gave up their petroleum leases in 1997 within the boundaries of the reserve area. Negotiations are continuing on cooperative management of the area by the federal government and the Haida Nation.

How are health and safety protected in the offshore petroleum industry?

The sinking of the drilling rig *Ocean Ranger* in February 1982 on the Grand Banks off Newfoundland, with the loss of 84 lives, and the fire and explosions on the *Piper Alpha* production platform in the North Sea in July 1988, with a loss of 167 lives, opened all eyes to the harsh realities of offshore petroleum operations. Subsequent investigations revealed the need to improve safety planning and performance. Lessons learned from those accidents prompted governments and industry around the world to improve safety planning, systems and equipment in the offshore oil and gas industry. These enhancements include the development of comprehensive safety management systems and mandatory reviews of all safety hazards before projects or activities are approved.

Offshore operators and governments have developed processes to review potential safety hazards and methods to minimize risks before any project begins. As well, companies fully include workers in planning, developing and implementing their health and safety programs. The focus is on continuous health and safety improvement at all levels. Offshore operators must adhere to strict health and safety requirements, administered by the federal-provincial regulatory boards in Newfoundland and Labrador and Nova Scotia and by the National Energy Board in the Arctic.

Health and safety management systems are generally based on the widely recognized Plan-Do-Check-Act cycle, which has continuous improvement as its key objective. The industry's primary focus is to prevent injuries or incidents from ever happening. But because not every risk can be eliminated, programs must be developed and tested regularly.

In the early stages of a project, companies spend months designing their operations and programs to prevent accidents. This process includes:

- identifying workplace hazards and risks – including extreme weather, fires and collisions – and taking steps to eliminate or control them.

During a training session, personnel climb down the escape chute from the platform to life rafts attached to the bottom of the chute. *Photo from HMDC.*

- carefully assessing the qualifications and competencies of all offshore workers. Selected workers receive orientation and training to ensure they understand the hazards present on the job and how to carry out their work in a safe manner. This preparation extends to rigorous training at special safety facilities on shore. For example, workers must be able to get out of an upside-down helicopter passenger compartment in a swimming pool before they are allowed to fly to an offshore platform.

All offshore production facilities undergo detailed safety reviews at every stage of project planning, design and construction, as well as periodic inspections during construction. The reviews ensure that drilling rigs, production and diving installations, and accommodation facilities contain all the necessary safety systems and equipment. Any such facility must meet the safety standards of the Canadian Coast Guard and the offshore petroleum boards or the National Energy Board. Each one must also be certified by an independent marine surveyor organization to be permitted to operate in Canadian waters.

As well, ships and helicopters used to support offshore activities must meet Canadian safety standards and be certified to operate in Canadian waters. Most companies have also developed their own additional safe operating practices that have resulted from years of working in extreme, remote environments. All offshore facilities and workers are equipped to deal with injuries or accidents. For example, production facilities must have medical and first aid supplies, fire protection systems, equipment failure alarms, emergency shutdown systems and emergency power and lighting systems. In an emergency, all workers must be familiar with escape routes, safe meeting areas and evacuation systems.

How are stakeholders consulted?

- *Government regulators and company policies require ongoing efforts to consult people affected by industry activities.*

Activities of the oil and gas industry often affect surrounding areas and populations. Stakeholders – individuals and groups with an interest in these activities – may include nearby residents, communities, Aboriginal people, landowners, recreational users, fishing and shipping interests, local businesses, environmental groups and various government agencies as well as the operating company, its employees and contractors. Industry associations, government regulators and individual companies have policies and guidelines to make sure stakeholders are consulted about industry operations.

Depending on the operation and its impacts, the public consultation can take many different forms. Major projects may involve formal public hearings. The methods used for consultation by the oil and gas industry include: public meetings, open houses, advisory committees, facility tours, meetings with town councils and community organizations, small group meetings, one-on-one meetings, workshop sessions, trade shows, telephone contacts, questionnaires, surveys, brochures, newsletters, exhibits, news releases, media interviews, advertisements and toll-free telephone numbers.

Additional recent initiatives to improve consultation include the formation in Atlantic Canada of the Nova Scotia Petroleum-Fisheries Liaison Group and a similar group, One Ocean, between the fisheries and petroleum industries in Newfoundland and Labrador.

This 50-person safety capsule aboard the Rowan Gorilla V jackup platform contains enough supplies for two weeks' survival. *Photo courtesy of Alex MacAulay/Ocean Resources.*

The B.C. and federal governments have emphasized that protecting coastal ecosystems is a crucial factor as they consider the possibility of renewed oil and gas exploration off the West Coast. *Photo by Armstrong Creative.*

Environmental Assessment Review Process
Canada-Nova Scotia Offshore Petroleum Board

All petroleum activity offshore Nova Scotia requires prior authorization from the Board and every work authorization application requires an environmental assessment.

Regulatory Step	**Environmental Assessment (EA)**
Pre-Call for Bids or during Call for Bids	The Board has conducted Strategic Environmental Assessment for Call for Bids since 1998. This process is under review.
Work Authorization Application	Environmental Assessments are submitted to the Board by the proponent as part of the authorization application. All EA's are reviewed using the Canadian Environmental Assessment Act (CEAA) process, which requires: 1. Project description 2. Scoping document (depending on level of review) 3. Environmental Assessment (EA) 4. Review of EA by responsible authorities The CEAA review process allows for a Screening, a Comprehensive Study or a Panel Review.
Work Authorization	
Geophysical or Geotechnical survey	Is reviewed using the Screening process. Information is posted to the Public Registry, but public comment does not necessarily have to be actively sought.
Drilling Program Authorization	If the wells referred to in the Drilling Program are being drilled in an area that has undergone a Panel Review or Comprehensive Study, then a screening can be used. If the area has not been covered by a Panel Review or a Comprehensive Study, then either a Panel or Study is required. A Comprehensive Study provides for active public consultation.
Application to Drill a Well (ADW)	The EA from the Drilling Program authorization covers the ADW.
Development Plan Application	Requires a Comprehensive Study or a Panel Review.

The above table is an example of the regulatory framework in place for the Nova Scotia offshore.
Source: Canada-Nova Scotia Offshore Petroleum Board.

Who regulates offshore exploration and production?

- *Joint federal-provincial agencies strictly regulate the East Coast offshore industry.*
- *The National Energy Board regulates Arctic exploration in co-operation with territorial governments, and it regulates all crude oil and natural gas exports.*
- *The regulatory structure for British Columbia has yet to be developed.*
- *Federal, provincial, territorial or Aboriginal authorities regulate virtually every aspect of the petroleum industry.*

The development of Canada's offshore wealth is tightly regulated to ensure resources are developed in a manner that balances environmental and economic considerations.

The Canada-Nova Scotia Offshore Petroleum Board and the Canada-Newfoundland Offshore Petroleum Board are joint federal-provincial agencies. They regulate offshore exploration and production activities under legislated accords established in the mid-1980s between the federal government and the two provincial governments.

The National Energy Board (NEB) regulates crude oil and natural gas exports and interprovincial and international transmission pipelines. The NEB and the Canada-Nova Scotia Offshore Petroleum Board jointly regulate the pipelines carrying Sable Offshore Energy Project natural gas. Provincial authorities regulate local distribution of natural gas and set environmental standards for onshore facilities such as crude oil storage, natural gas and liquids processing, oil refining and petroleum products distribution.

Offshore oil and gas activities also are subject to various policies and regulations established by agencies such as the Canadian Environmental Assessment Agency, Department of Fisheries and Oceans, Indian and Northern Affairs, Environment Canada, Labour Canada, Transport Canada, and the relevant provincial, territorial and Aboriginal authorities such as the Inuvialuit in the Northwest Territories. Virtually every industry activity is subject to some form of permit, approval or authorization.

The regulatory structure for British Columbia will depend on the collective decisions of the federal and provincial governments. Both have emphasized that they will address the needs of residents, particularly First Nations and coastal residents.

East Coast Offshore and Arctic licences

Off the East Coast and in the Arctic, licences are auctioned to companies on the basis of spending commitments that must be honoured within a fixed period of time. If commercial quantities of crude oil or natural gas are found, the company retains the mineral rights. Initially, royalties are paid to the government at a low rate until exploration and development costs are recovered, at which time royalty rates escalate according to a set schedule. Some Arctic regions have First Nations ownership as well as federal, and First Nation entities issue their own permits or licences to conduct operations on their lands, subject to their own royalty regimes.

5 Canada's offshore projects

The rich crude oil and natural gas discoveries made off Canada's East Coast have resulted in the following offshore projects.

- **Cohasset-Panuke – Nova Scotia**
- **Hibernia – Newfoundland and Labrador**
- **Sable Offshore Energy – Nova Scotia**
- **Terra Nova – Newfoundland and Labrador**
- **White Rose – Newfoundland and Labrador**

Cohasset-Panuke – Nova Scotia

THE PROJECT Cohasset-Panuke was Canada's first offshore petroleum production development, located near Sable Island, roughly 250 kilometres off Nova Scotia. Production of high-quality, light crude oil began from these two fields in 1992, and later from the Balmoral field adjacent to Cohasset. Production peaked at 6,350 cubic metres per day in the mid-1990s and ceased in 1999. Total investment in the project was about $1 billion.

THE METHOD The Cohasset-Balmoral and Panuke fields each had production facilities, which were connected by 22.5 kilometres of subsea pipeline. Drilling and production operations were conducted from a jackup platform, supported by retractable legs planted on the ocean floor. The platform can be moved from one field to the other as needed. The produced crude oil was pumped into a large storage tanker, offloaded into a smaller shuttle tanker and shipped to markets in Canada, Europe and the United States.

production

Hibernia – Newfoundland and Labrador

THE PROJECT Hibernia is located on the Grand Banks, 315 kilometres east-southeast of St. John's, Newfoundland and Labrador. Crude oil production from the $5.8-billion project began in November 1997. Production rose each year from 15,000 cubic metres per day in 1998 to more than 30,000 cubic metres per day in 2003.

THE METHOD Oil is produced and stored in a massive concrete structure that rests on the sea floor, 80 metres below the surface. The 24 oil-producing wells extend up to nine kilometres diagonally and horizontally from the platform. Additional wells are used to inject seawater and reinject produced natural gas into the reservoir formations, to maintain reservoir pressure and conserve the natural gas. Crude oil is shipped by double-hulled shuttle tankers directly to market or to a transshipment terminal at Whiffen Head on the south coast of the island of Newfoundland. Other tankers carry the oil from the terminal to markets in Canada and the United States. Production is expected to continue for about 20 years.

Sable Offshore Energy – Nova Scotia

THE PROJECT The $2-billion Sable Offshore Energy Project began producing natural gas and natural gas liquids in late 1999. The producing facilities are located near Sable Island, 225 kilometres east of the Nova Scotia coast. Wells tap into natural gas fields estimated to contain more than 65 billion cubic metres of natural gas. Production in 2003 was about 13 million cubic metres per day.

THE METHOD Offshore facilities will eventually include six steel production platforms, of which four were in operation by the end of 2003. Jackup rigs move from site to site to drill additional wells. A pipeline on the sea floor carries natural gas and natural gas liquids to shore. Onshore facilities include a natural gas processing plant and a fractionation plant to remove natural gas liquids such as propane and butane. A $1-billion transmission pipeline carries the natural gas to markets in Nova Scotia, New Brunswick and the northeastern United States. The natural gas liquids are sold separately. Production is expected to continue for up to 20 years as additional fields are developed in the area.

Lighting is crucial for "24/7" operations on the Hibernia platform. *Photo from HMDC.*

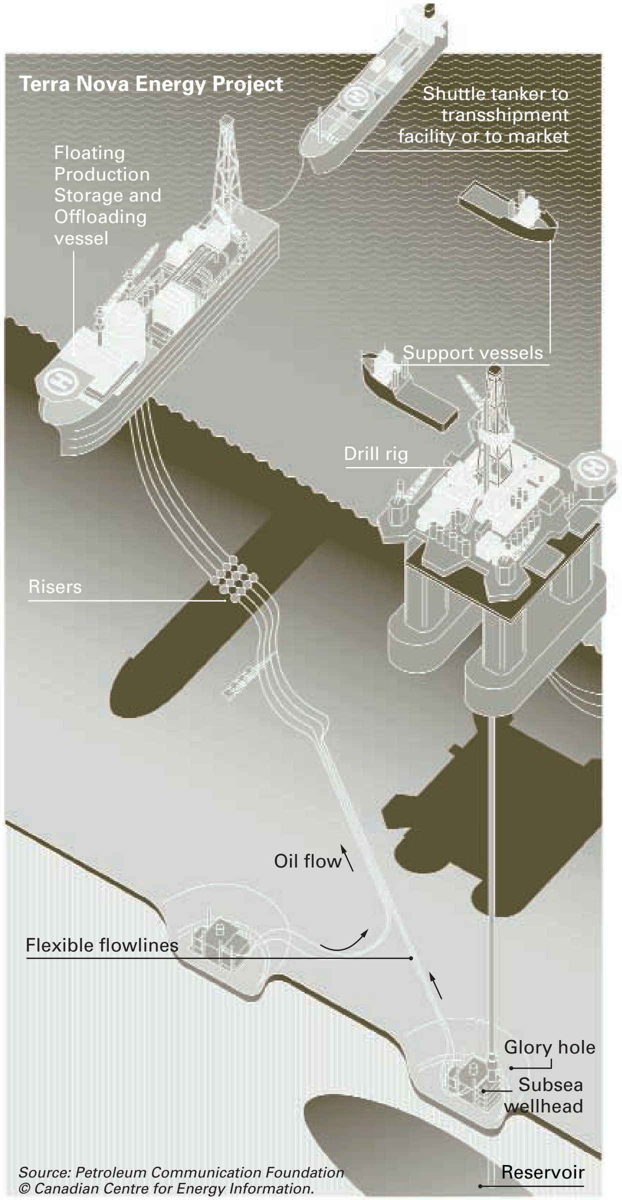
Terra Nova – Newfoundland and Labrador

THE PROJECT This $2.8-billion project began production in 2002, and has a maximum approved production rate of 28,620 cubic metres of crude oil per day. The field has an expected life of 15 to 17 years. The Terra Nova field is located 350 kilometres east-southeast of St. John's, Newfoundland and Labrador.

THE METHOD A floating production, storage and offloading (FPSO) vessel is used to produce crude oil from the field. This vessel is a ship-shaped production platform with integrated oil storage from which oil is offloaded to a shuttle tanker. One of the largest such vessels ever built, the Terra Nova FPSO is 292.2 metres long. The vessel can store 152,600 cubic metres of crude oil and accommodate up to 80 personnel.

Oil production wells are pre-drilled by a semi-submersible drilling platform. The wellheads and production manifolds are placed in "glory holes" – excavations in the sea floor – that protect the equipment from scouring icebergs. A network of

Eirik Raude, a semi-submersible drilling vessel that drilled an exploration well in very deep water offshore Nova Scotia in 2003. The Eirik Raude and its sister ship are the largest semi-submersible vessels in the world.
Photo courtesy of Imperial Oil Limited.



more than 40 kilometres of flexible flowline is used to convey hydrocarbons to and from the wells. Produced gases are separated from the oil and re-injected into the reservoir for possible future extraction.

The connection between the FPSO and the subsea flowlines is the spider buoy. The spider buoy is the mooring point for the FPSO, and the pathway for oil and fluids that flow to and from the FPSO and reservoir. The spider buoy has a quick-disconnect feature, allowing the FPSO to disconnect and leave the area in an emergency situation such as the approach of an iceberg. Double-hulled shuttle tankers carry crude oil from Terra Nova directly to market or to the same transshipment terminal in Newfoundland and Labrador used by the Hibernia project.

White Rose – Newfoundland and Labrador

THE PROJECT The $2.35-billion White Rose project is expected to begin production in late 2005 or early 2006, and is expected to produce up to 14,600 cubic metres of crude oil per day. The White Rose field is located about 350 kilometres east of St. John's, Newfoundland and Labrador.

THE METHOD A floating production, storage and offloading system, similar to the Terra Nova facility, will be used for White Rose.

Additional Grand Banks discoveries

Three other oilfields – Hebron, Ben Nevis and West Ben Nevis – have been identified in the Grand Banks area for possible development as part of a single project. This project could benefit from expertise and onshore facilities, such as fabricating yards and the transshipment terminal, developed for Hibernia, Terra Nova and White Rose. Substantial natural gas has also been found off Newfoundland and Labrador, including the natural gas associated with the oilfields, and new technologies such as compressed natural gas tankers are under study as one possible means of bringing this natural gas to markets.

6 A half-century of searching

When did offshore exploration begin?

- Canada's offshore industry was launched in the 1940s when the first well was drilled off Prince Edward Island.
- Exploration really began in earnest in the 1960s, but high investment and little return marked this period.
- Major successes came in the 1970s and 1980s as knowledge was gained and exploration techniques advanced.
- Seismic surveys began off the West Coast in 1958, and 14 wells were drilled there between 1967 and 1969.
- The first offshore well in the Beaufort Sea was drilled in 1972, and the major Amauligak discovery occurred in 1984.

In the 1940s, Canadians launched what would become an epic search for crude oil and natural gas off the country's vast coastline. A half-century of effort was invested off the East, West and Arctic coasts before the first commercial quantities of crude oil were produced off Nova Scotia in 1992. Canada was one of the pioneers in many aspects of offshore exploration, although development and production initially proceeded more rapidly in regions such as the Gulf of Mexico and the North Sea, giving their industries the lead in some offshore technologies. With developments during the past decade, Canada is again moving into the forefront.

Sedco semi-submersible platform,
Victoria, circa 1967.
Photo courtesy of Shell Canada Limited.

Selected significant discoveries

GAS	
Thebaud	1972
Venture	1979
South Venture	1983
Glenelg	1983
Alma	1983
Chebucto	1984
North Triumph	1986
OIL	
Cohasset	1973
Hibernia	1979
Hebron	1981
Terra Nova	1984
Whiterose	1985
Panuke	1986
West Bonne Bay	1998

Source: Newfoundland Ocean Industries Association

Canada's first offshore well was drilled between 1943 and 1945 in eight metres of water, 13 kilometres off Prince Edward Island. Hillsborough No. 1 was drilled from an artificial island made of wood, rock and concrete. It reached a depth of 4,479 metres before it was abandoned without encountering oil or natural gas. At a cost of $1.25-million (equivalent to $14 million in 2003 dollars), it was one of the most expensive wells ever drilled at the time.

Geological and geophysical studies continued into the 1950s, and exploration really began in earnest in the 1960s. This was made possible by the introduction of jackup and semi-submersible drilling systems in the world petroleum industry in the 1950s. For the West Coast drilling, a semi-submersible was built in Victoria, B.C. in the 1960s. However, the first decade of drilling was marked by high investment and little return.

The first well on Sable Island was drilled in 1967, but had to be abandoned when it encountered higher-than-expected downhole pressures in a natural gas reservoir that would have exceeded the safety limits of the equipment. At the time, companies were mainly looking for crude oil, and there was not much interest in developing the natural gas. This was also the case with the natural gas discovered off Tofino on Vancouver Island during drilling of 14 wells off the West Coast between 1967 and 1969.

Other minor discoveries were made during that first decade of exploration off the Nova Scotia coast – including the Cohasset oilfield in 1973. But development of that oilfield did not occur until after the nearby Panuke crude oil discovery in the 1980s, which led to the Cohasset-Panuke project.

The federal and provincial governments imposed moratoria on drilling off the West Coast in 1972, largely because British Columbians strongly opposed tanker shipment of Alaskan crude oil through the Inside Passage along their coast. The Inside Passage proposal was dropped, but the moratoria remained in place. Between 1984 and 1988, the federal and B.C. governments considered lifting the ban and even conducted a seismic survey to reassess the resource, but ironically another Alaskan event – the Exxon Valdez oil spill in 1989 – intervened. The issue was dropped again until 2001, when new studies began.

In the Arctic, the first offshore well was drilled from an artificial island in the Beaufort Sea during the winter of 1972-73. But the only actual offshore production was a tanker-load of crude oil that was shipped to Japan following an extended production test of the Amauligak well in 1986.

Success also eluded the offshore industry when it first began drilling in 1966 on the Grand Banks, off Newfoundland and Labrador. The first 40 wells – with only one exception – failed to find commercial quantities of oil or natural gas. A decade of exploration from 1973 to 1983 in the iceberg-prone waters off Labrador found substantial natural gas reserves but failed to find commercial crude oil resources.

Despite these setbacks, the petroleum industry was undeterred. The industry's tenacity paid off in 1979 with two finds that marked the beginning of a string of crude oil and natural gas discoveries:

- The Venture natural gas discovery near Sable Island was the first of six natural gas fields that now make up the Sable Offshore Energy Project, which began production in 1999.

Maersk Nascopie, a large platform supply vessel, off Newfoundland and Labrador. *Photo from HMDC.*

- Also in 1979, the Hibernia crude oil discovery began a new chapter on the Grand Banks. Development approval for Hibernia was received in 1986, but a drop in world oil prices shelved the project until the 1990s.

How are offshore crude oil and natural gas deposits found?

- *Petroleum scientists develop "pictures" of underground rock formations through a process called seismic surveying.*
- *Powerful computers help create an image of underground rock features that could contain crude oil and natural gas.*
- *However, drilling a well is the only way to determine the quality and quantity of crude oil or natural gas hidden in the pores of deeply buried rocks.*

Scientists in the petroleum industry use a variety of techniques to "look" inside the Earth's crust and locate crude oil and natural gas deposits. This challenging task becomes even more difficult in offshore regions because the rocks are covered by water.

Crude oil and natural gas are found in sedimentary rocks, formed by the accumulation of organic sediments over millions of years. An area that contains thick layers of this type of rock is called a sedimentary basin. Contrary to common belief, crude oil and natural gas are not found in lakes or caverns under the Earth's surface. In reality, the hydrocarbons are contained in the pores of rocks, much like water in a sponge.

Exploration of sedimentary basins begins with a search of academic papers, data from agencies such as the Geological Survey of Canada, and previous exploration results from nearby or similar areas.

In Canada, government regulations ensure that the information obtained during exploration is eventually made public. The Canada-Nova Scotia Offshore Petroleum Board and the Canada-Newfoundland Offshore Petroleum Board hold all seismic and drilling information gathered about regions off the East Coast under their jurisdictions. The National Energy Board holds scientific data from other offshore areas.

Seismic surveys

If there is little or no existing information about an area under exploration, petroleum scientists must develop their own "picture" of the underground rock formations. This is done through a process called seismic surveying.

Geophysicists and geologists use seismic surveys to help locate drilling prospects that might contain crude oil and natural gas. This technique also allows them to compare the area under study with other petroleum-producing areas.

In offshore seismic surveys, compressed-gas air guns are used to make sound waves that travel into the ocean floor. A ship tows an array of sensitive receivers called hydrophones. These receivers record the sound waves that are reflected back from the various rock layers beneath the ocean floor. In most cases, the hydrophones are towed behind the seismic vessel at a depth of about 10 metres below the surface, but in shallow waters, the hydrophones may be laid directly on the seabed.

Exploration support services

- Drilling Rigs
- Supply Vessels
- Helicopter Services
- Shorebase
- Well Testing
- Wireline Logging
- Cementing
- Drilling Fluids
- Wellheads
- Directional Drilling
- Mud Logging
- Coring
- Solid Controls
- Offshore Communications
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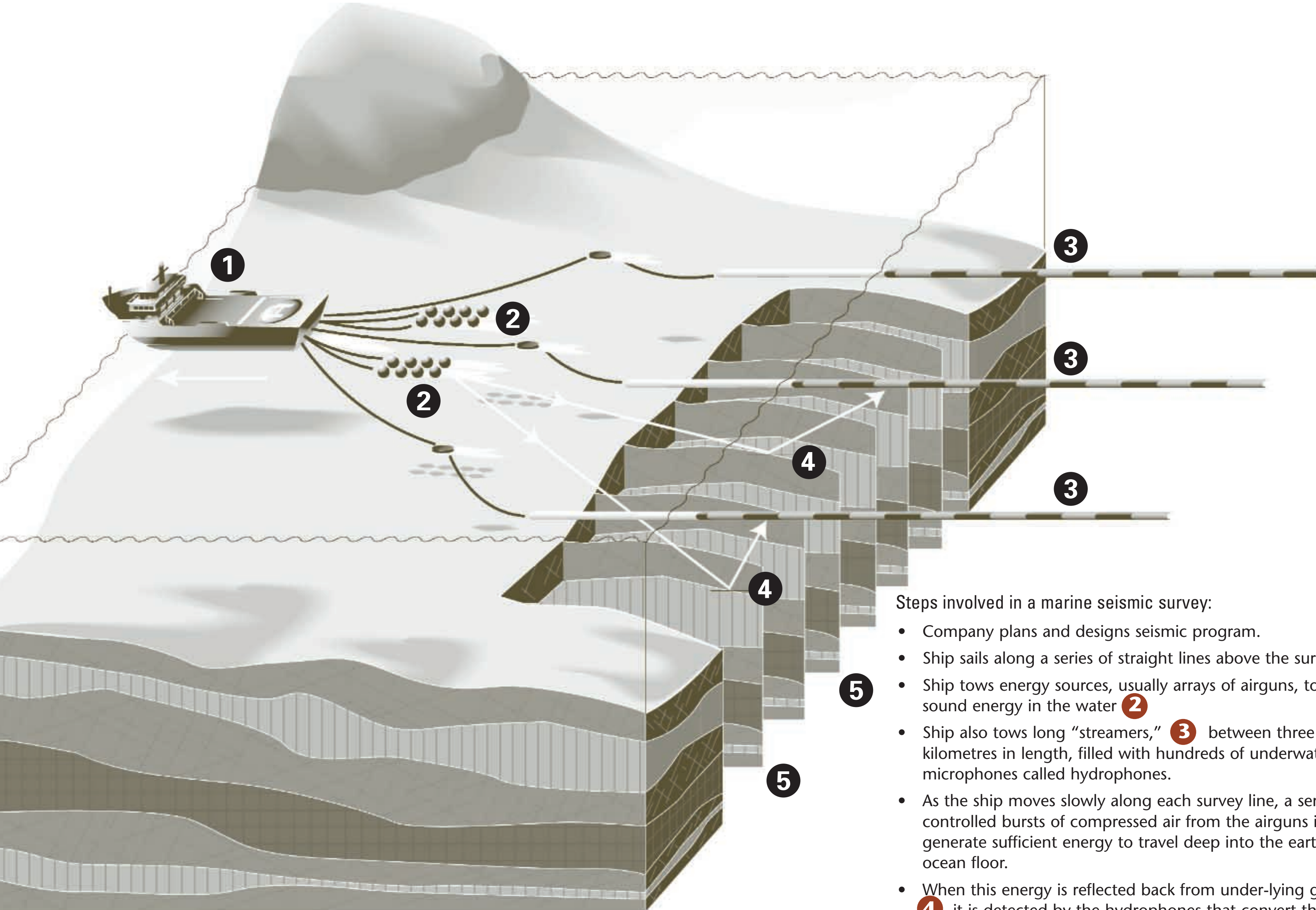
Source: Newfoundland Ocean Industries Association.



Source: Veritas DGC Inc. / Petroleum Communication Foundation.
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Steps involved in a marine seismic survey:

- Company plans and designs seismic program.
- Ship sails along a series of straight lines above the survey area 1
- Ship tows energy sources, usually arrays of airguns, to produce sound energy in the water 2
- Ship also tows long "streamers," 3 between three and six kilometres in length, filled with hundreds of underwater microphones called hydrophones.
- As the ship moves slowly along each survey line, a series of controlled bursts of compressed air from the airguns in the water generate sufficient energy to travel deep into the earth below the ocean floor.
- When this energy is reflected back from under-lying geologic strata 4 it is detected by the hydrophones that convert the energy into electrical impulses which are then transmitted back along the streamers to the ship to be recorded on magnetic tape.
- The data on the magnetic tapes are processed, often onboard the vessel, to create sonic images of the subsurface.
- The result is a series of lines of recorded seismic data 5 that together yield a graphic 3D representation of subsurface geologic structure, enabling interpreters to decide where to drill for oil or gas.

Geophysical vessels conduct a seismic survey of the oil-bearing rocks thousands of metres beneath the sea floor around the Hibernia platform. *Photo courtesy of the Canada-Newfoundland Offshore Petroleum Board.*

Offshore seismic surveys require government approval and must comply with strict environmental regulations, including a pre-survey environmental assessment. Programs are designed to avoid fish spawning seasons and sensitive fishery areas. During the first half-hour of a survey, the energy level of the discharges is gradually increased so that fish and mammals have an opportunity to move out of the area.

The data from a single line of hydrophones gives a two-dimensional or 2D view, like a single slice through an apple. Several lines of hydrophones produce a three-dimensional or 3D picture. In an apple, 3D might show the dimensions of a wormhole that would have been missed entirely in the 2D picture. While 3D is considerably more expensive, it provides far more detailed and reliable information.

A new four-dimensional or 4D technique involves shooting 3D seismic in exactly the same location at different times – perhaps months or years apart. This monitors changes as crude oil or natural gas is drawn out of the reservoir, and identifies locations where crude oil or natural gas remains. It is the equivalent of watching the progress of the worm going through the apple via a series of snapshots at different times.

Geophysicists use powerful computers to process the data collected by seismic surveys. By filtering extraneous noise and enhancing the desired signals, computers identify different rock layers and structures. Computer-assisted processing creates an image of the sedimentary features below the surface. This image contains important information about the location and shape of underground rock layers that could hold crude oil and natural gas.

Significant improvements in the gathering, processing and display of seismic data in recent years have made it possible for geophysicists to pinpoint promising geological formations much more accurately. However, the only way to determine what the rocks actually contain is to drill a well.

Interpreting three-dimensional seismic data using a computer work station.
Photo courtesy of the Canada-Newfoundland Offshore Petroleum Board.

7 Facilities and methods

What platforms are used for offshore exploration and production?

- Platforms that can house drilling rigs, production facilities and crew quarters are used to find and produce offshore crude oil and natural gas.
- The Hibernia crude oil project uses a structure that is 224 metres tall and weighs 1.2 million tonnes.
- Floating production, storage and offloading vessels for the Terra Nova and White Rose projects are up to 292 metres long and each can hold more than 150,000 cubic metres of crude oil, equivalent to more than a week's production at peak rates.
- The Thebaud platform provides accommodation and processing facilities for the Sable Offshore Energy Project.
- Several types of platforms are used for exploratory drilling off the East Coast.
- Artificial islands, ice structures, steel structures and drillships have all been used in Arctic offshore exploration.

The big difference between the onshore and offshore petroleum industry is the need for robust equipment that can operate in a dynamic and often hostile marine environment. Canadian companies have combined technology and innovation to create offshore facilities that can withstand the challenges posed by deep water, harsh weather conditions, pack ice and icebergs.

systems

Rowan Gorilla II jackup platform offshore Nova Scotia. *Photo courtesy of Rowan Companies Inc.*

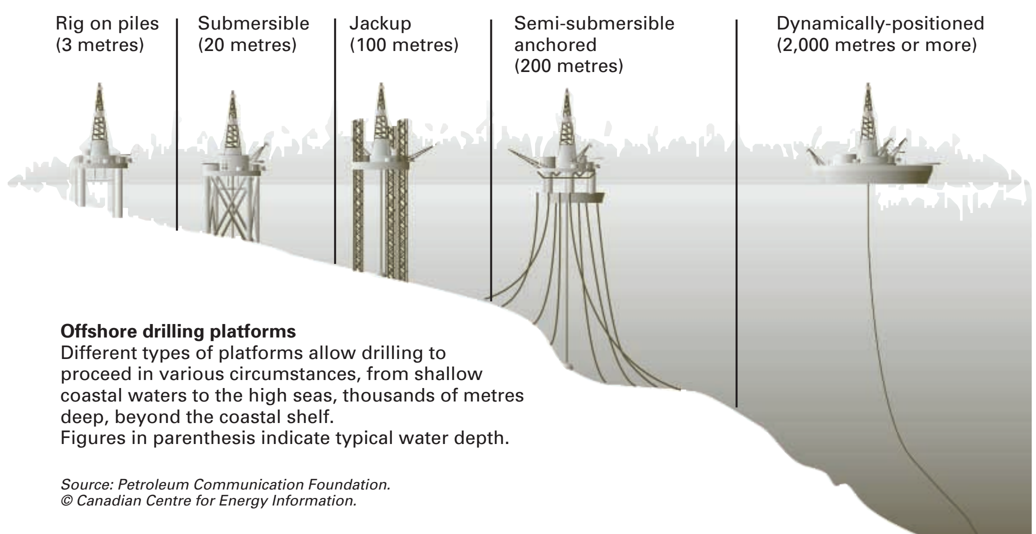
The East Coast offshore industry uses platforms that can house crew quarters and drilling or production facilities. Both drilling and production are conducted from the Hibernia platform; other East Coast operations use mobile jackup or semi-submersible rigs or drillships to drill wells, which then are connected to production facilities. Producing facilities also need to contain processing equipment to separate crude oil, natural gas and water, and to remove impurities. For crude oil, facilities also need storage capacity for the oil. These platforms operate hundreds of kilometres off the East Coast on the continental shelf. The water depth varies from 30 metres around Sable Island to 125 metres around White Rose. This is still considered "shallow" by world standards.

The type of platform used depends on water depth and risk of icebergs, as well as the economics, characteristics and production life of the resource. In shallow water, less than 25 metres in depth, the platform could rest on pilings planted on the sea floor. Jackup platforms have legs that can be raised or lowered for use in moderate depths, up to 150 metres but generally 30 to 80 metres in waters off the East Coast. In deeper waters, semi-submersible platforms or drillships are used for exploration, and floating facilities are used for production.

Dynamically positioned drillships and most semi-submersible rigs use propellers and thrusters to maintain position. Drillships are usually employed for drilling in very deep waters. Such drillships were used to drill wells off Nova Scotia in 2002 and 2003 at water depths of more than 1,600 metres. In the Arctic, wells have been drilled from artificial islands constructed of material dredged from the ocean floor, earth-filled steel structures, ice-strengthened conventional drillships and even from ice platforms.

The facilities used to produce natural gas off Nova Scotia are quite different than those used in crude oil production on the Grand Banks off the east coast of Newfoundland. This is

Various types of marine riser and drilling pipe are stockpiled aboard an offshore platform. *Photo courtesy of Ocean Rig.*



Offshore drilling platforms
Different types of platforms allow drilling to proceed in various circumstances, from shallow coastal waters to the high seas, thousands of metres deep, beyond the coastal shelf.
Figures in parenthesis indicate typical water depth.

Source: Petroleum Communication Foundation.
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Maersk Frontier, a large platform supply vessel.
Photo courtesy of Seabase/Maersk.

due to the different commodities involved as well as the threat of icebergs in the waters on the Grand Banks.

The Hibernia crude oil project uses a massive gravity-based structure that sits on the ocean floor. The structure is 224 metres tall and weighs 1.2 million tonnes. This type of structure was selected because it can handle extreme storm conditions, sea ice and icebergs. The Hibernia platform is designed to withstand an encounter with a six-million-tonne iceberg. However, the largest icebergs in the North Atlantic would run aground before they threatened the platform.

At 80 metres in depth, the water around Hibernia is considered shallow. Although the resource is large, it is located in a relatively small area, and is expected to have a production life of at least 20 years. All these factors helped justify the added expense of Hibernia's massive concrete structure.

The Terra Nova and White Rose projects are respectively located 35-40 kilometres southeast and east of the Hibernia platform, in waters up to 125 metres deep. Although close in proximity, a very different production system was chosen for these projects. If threatened by icebergs, the floating facilities can be detached from wellheads on the seabed and moved away.

The Terra Nova and White Rose wellheads are in excavated "glory holes" in the ocean floor to protect them if icebergs move through the field. The floating facilities are also less costly, which is suited to a smaller resource with a shorter production life. Future projects in the area will likely use similar systems, and possibly share some processing, storage or transportation facilities with the Terra Nova, White Rose and Hibernia projects. However, gravity-based structures like Hibernia may be considered if larger fields are found and developed in the ice-prone region.

The waters around Sable Island off Nova Scotia are not frequented by icebergs and are also relatively shallow – generally 30-40 metres deep, making it possible for the Cohasset-Panuke crude oil project and Sable Offshore Energy Project to use production structures supported by steel legs standing on the sea floor. In the Sable project, jackup drilling rigs are used to drill wells that are then connected by pipeline to the permanent production platforms. The Sable Offshore Energy Project also includes a pipeline laid in a trench on the sea floor to carry the raw natural gas to onshore processing facilities.

How are wells drilled offshore?

- *A revolving bit at the end of a string of pipe grinds a hole through rock layers.*
- *Directional and horizontal wells are drilled out into the rock formation to reach a larger area of the reservoir.*

New technologies have substantially reduced the cost of drilling offshore wells. But the price tag is still quite high – $30 million to $100 million or more. That is many times the cost of drilling a typical well on land.

Many of the drilling methods used on land are also used in offshore operations. Both drilling derricks look similar. However, an offshore rig's drilling apparatus is permanently assembled on the ship or platform, while a land-based rig can be taken apart and moved from site to site.

The rigs operate around the clock, seven days a week. Crews typically work 12-hour shifts for up to three weeks and then have up to three weeks off.

A supply vessel prepares to tow a large iceberg away from the drilling area on the Grand Banks. *Photo courtesy of Provincial Airlines Limited.*

The drilling process

The basic drilling process is simple. A bit rotates at the bottom of a string of pipe, called the drill string, to grind a hole through the rock layers. The bit may be studded with tungsten carbide or industrial diamonds to reduce wear and tear and to penetrate harder rock formations. Improvements in bit design and materials in recent years have made it possible for drills to penetrate much further before the need for a costly bit change, which involves pulling the entire string out of the hole.

A fluid called drilling mud circulates through the drill bit as it cuts through the rock. The mud – a suspension of chemicals and minerals in water or oil – is used to lubricate and cool the bit, remove rock cuttings, and prevent cave-ins of the well bore. As the bit penetrates deeper, the crew threads additional pipe onto the top of the string – often using remote-controlled hydraulic equipment. Sections of pipe are typically 9.1 metres long, but may be longer. The pipe's diameter and wall thickness vary, depending on well depth.

Most offshore rigs now use top drives – hydraulic or electric motors suspended above the drill string. In some situations, the bit can be turned by a mud motor, a downhole hydraulic drive that is inserted above the bit at the bottom of the drill string. It receives power from the flow of the drilling mud.

This technique is often used to drill directional and horizontal wells, which are important to offshore operations. Directional drilling allows a number of wells to be drilled from one location. Horizontal wells can penetrate a long section of the rock formation, providing better contact with the reservoir. This reduces the time it takes to extract crude oil or natural gas from the reservoir and in some cases increases the total amount of product that can be recovered. As drilling technologies and methods have improved, the "reach" of wells into producing formations continues to increase.

On the Hibernia project, wells extend up to seven kilometres out from the platform's base, three or four kilometres below the ocean floor. In fact, a 9,357-metre well drilled in late 2003 was the longest ever drilled in Canada and was ranked as the longest in the world at this vertical depth. Eventually, it is expected that more than 80 wells will be drilled from Hibernia. If current trends continue, wells could eventually extend 10-15 kilometres out from a platform.

The Hibernia platform has a design capacity of 21,500 cubic metres to 23,850 cubic metres of oil per day. *Photo courtesy of Chevron Canada Resources-HMDC.*

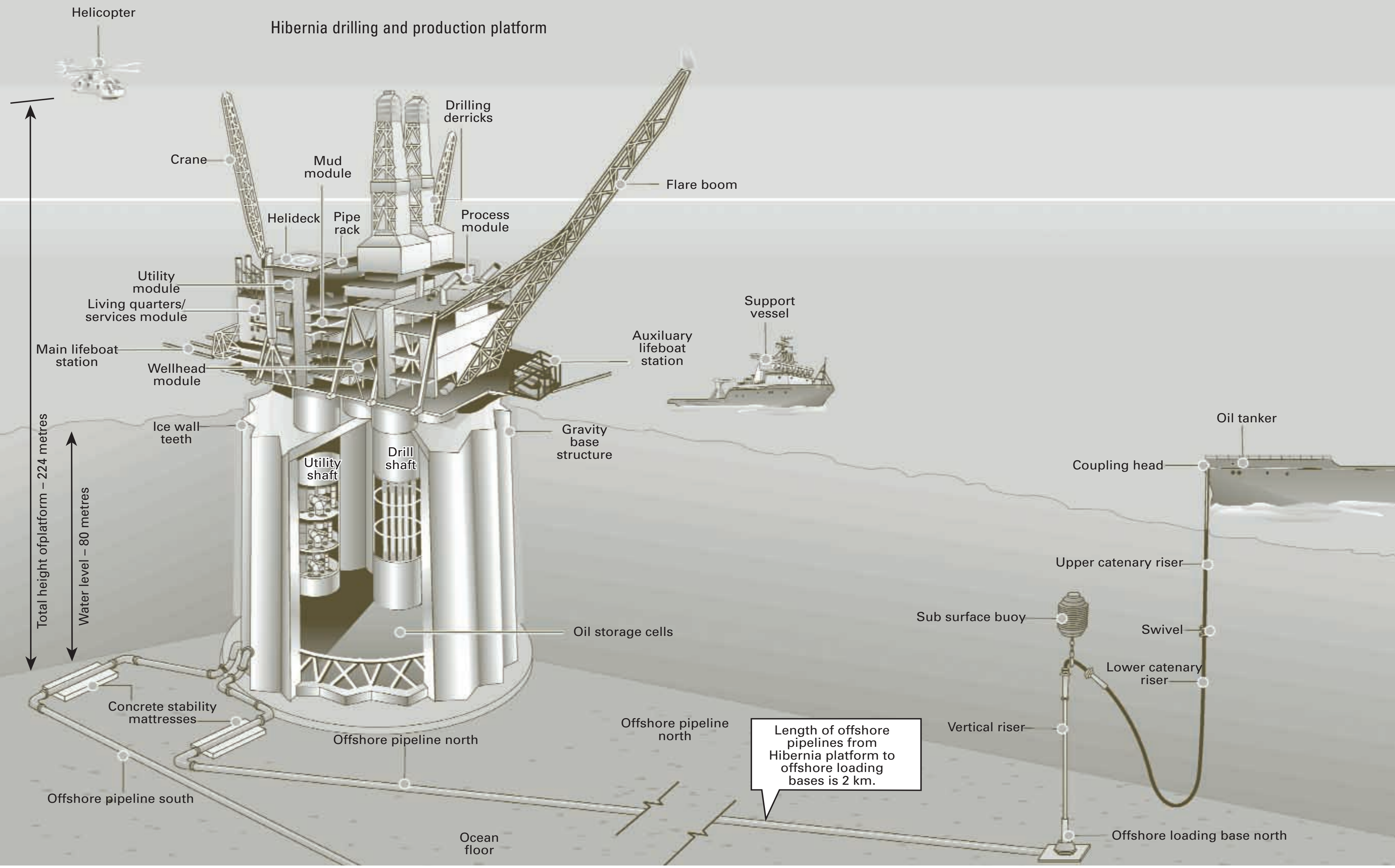
Stages of drilling

In subsea drilling, a structure called a template is cemented in place on the sea floor to establish a connection between the rig and the well bore. The template is basically an open steel box with multiple holes in it, depending on the number of wells to be drilled. Automatic shutoff valves, called blowout preventers, are later attached to the template so that the well can be sealed off if there are problems on the platform or the rig has to be moved. Cables attach the template to floating platforms; the cables are used to position the drill pipe accurately in the template and wellbore, while allowing for some vertical and horizontal movement of the platform.

The first stages of drilling penetrate 500 to 1,000 metres below the sea floor, after which steel casing is cemented into the hole. Combined with the blowout preventers, the casing helps to prevent crude oil or natural gas from escaping into the environment.

One of the primary differences between onshore drilling and offshore drilling is that, in offshore drilling, a large pipe

Hibernia drilling and production platform



Source: Hibernia Management and Development Company Ltd.

A telescopic joint provides the link between the marine riser and the drilling rig on an offshore platform. The riser is in turn connected to the blowout preventers and template on the sea floor. *Photo courtesy of Ocean Rig.*

called a riser is used to connect the drilling rig to the seabed. The riser is not in place during the drilling of the shallowest part of the hole, but is installed after the casing has been cemented in place. The riser acts as a conduit for the drilling mud and drill cuttings which must be circulated through the well bore and back to the drilling rig so that the cuttings can be removed for disposal. The cuttings are studied carefully by the wellsite geologist as drilling progresses.

The drill bit may be several kilometres deep by the time high-pressure crude oil and natural gas deposits are reached. Drillers control the pressure between the reservoir and the well by adjusting the flow and weight of the drilling mud. The mud must be heavy enough to keep reservoir fluids from entering the hole during drilling, but not so heavy that the mud penetrates the rock and prevents crude oil and natural gas from reaching the well.

The first sign of success is usually an increase in the rate the drill bit penetrates the rock. This is often followed by traces of crude oil or natural gas in the rock cuttings brought up by the drill bit. This stage of drilling is carefully monitored to prevent releases of crude oil and/or natural gas that might affect the environment.

Logging and testing

Important information is gathered during drilling. Wireline logging tools gather data about the rock layers' thickness, porosity, permeability and the composition of the fluids (oil, natural gas or water) contained in them. These tools can be mounted on the drill string above the bit to send information to the surface continuously during drilling, or they can be lowered into a well after it is drilled.

Another instrument, called a measurement-while-drilling (MWD) tool, can also measure the direction and precise location of the bit while drilling horizontal wells.

A common way to determine potential oil or natural gas production is the drillstem test. A special tool replaces the bit on the end of the drill string and is lowered into the well. It allows liquids or natural gas from the formation to flow into the empty drill pipe. This gives a good indication of the type and volume of the fluids in the formation, their pressure and rate of flow.

Regulations require that the sea floor at any well site must be left in the same condition after drilling as before. This means that the drilling crew plugs the well bore with cement and removes the subsea equipment. A similar procedure is followed when a producing well is no longer economical to operate.

How is offshore petroleum produced?

- *Tubular casing lines the length of the well bore to ensure safe control of crude oil and natural gas.*
- *Natural gas flows to the surface under its own pressure, but oil may need to be coaxed to the surface.*

Producing crude oil and natural gas from offshore locations is very similar to the process used on dry land. The same procedures and equipment are used, but generally in a smaller area.

Crude oil and natural gas wells are prepared for production through a process called completion. In the first step, a production casing is cemented into the well bore.

A series of blowout preventers, linked together in a "BOP stack," are used to control pressure while wells are being drilled. Valves in the preventers can shut down fluid circulation quickly and safely in the event of an emergency or an unexpected encounter with high-pressure crude oil or natural gas. *Photo courtesy of EnCana Corporation.*

Life aboard the Rowan Gorilla V jackup platform. *Photo courtesy of Alex MacAulay/Ocean Resources.*

Workers load pipe onto a supply vessel in St. John's harbour. Many types of pipe, casing and riser are used in offshore exploration and production. *Photo from HMDC.*

The casing – tubular steel pipe connected by threads and couplings – lines the total length of the well bore to ensure safe control of the crude oil and natural gas, prevent water entering the well bore and keep rock formations from sloughing into the well bore.

Once the cement has set, the production tubing can be put in place. Production tubing is steel pipe that is smaller in diameter than the production casing. Production tubing was traditionally made up of joined sections of pipe, similar to the string of pipe used for drilling, but most offshore wells today use coiled tubing, a continuous, high-pressure-rated hollow steel cylinder.

Production tubing is lowered into the casing and hangs from a sea floor installation called the wellhead. The wellhead has remotely operated valves and chokes that allow it to regulate the flow of oil and gas.

The casing is then perforated to allow crude oil and natural gas to flow into the well. This is done with a perforating gun, an arrow of shaped explosive charges that is lowered into the well. An electrical impulse fires the charges that perforate the casing, surrounding cement and reservoir rock.

Natural gas flows to the surface under its own pressure, but oil may need to be coaxed to the surface by pumping in the later stages of a well's lifespan. In many crude oil and natural gas wells, the formation must also be stimulated by physical or chemical means. This procedure creates channels beyond the perforations that allow crude oil and natural gas to flow back to the well.

The two most common stimulation methods are acidizing and fracturing (also known as "fracing"). Acidizing involves injecting acids under pressure through the production tubing and perforations and into the formation. Fracing involves pumping a fluid, such as a water gel, down the hole under sufficient pressure to create cracks in the formation. Whether these techniques are used depends on a number of factors, including potential environmental impacts as well as the geology of the reservoir.

Subsea pipelines can be used to connect multiple offshore wells to processing and transportation facilities. Subsea pipelines were used for the Cohasset-Panuke project and play a key role in the Sable Offshore Energy Project, which also uses a major subsea pipeline from the production area to onshore facilities.

How is offshore crude oil processed and transported?

- *Processing facilities on offshore platforms remove unwanted fluids from crude oil before it is stored and shipped.*
- *Double-hulled, double-bottomed shuttle tankers are designed to transport crude oil from the offshore platforms to a transshipment terminal.*

Varying quantities of saltwater and natural gas are usually produced along with crude oil. Offshore production platforms include processing facilities that remove these fluids from the crude oil before it is stored and shipped.

The saltwater is reinjected into the producing formation to maintain pressure in the reservoir. The natural gas, often called solution gas, is used for heat and power on the platform, and the remainder is reinjected into the reservoir. The Hibernia project initially flared natural gas while injection wells were being drilled, and a small amount of natural gas is always flared to maintain an ignition source in case production operations are interrupted and gas must be diverted to the flare stack. New technologies such as compressed natural gas tankers are being investigated as a way to deliver the natural gas eventually to onshore markets.

Both Hibernia and Terra Nova include crude oil storage facilities onboard the production platforms. Double-hulled, double-bottomed shuttle tankers, specially designed for use in the waters off Newfoundland and Labrador, carry the crude oil from the platforms directly to market or to a transshipment terminal at Whiffen Head, Newfoundland and Labrador, for storage and transshipment to tankers that carry the oil to refineries.

Production from the Panuke and Balmoral oilfields flowed to the Cohasset platform through a subsea pipeline. The production from both fields was processed through facilities and equipment located on the platform. The oil was then stored in a specially adapted tanker called the Nordic Apollo and periodically transferred to a shuttle tanker for delivery to markets.

How is offshore natural gas processed and transported?

- *The Sable Offshore Energy Project removes saltwater from natural gas before it is shipped through a pipeline on the ocean floor to onshore processing facilities.*
- *A plant in Goldboro, Nova Scotia, removes natural gas liquids (propane, butane and pentanes) to produce marketable natural gas for consumers.*

Natural gas from the Sable Offshore Energy Project is gathered at the Thebaud production platform and compressed for shipment. It is shipped through a subsea pipeline to the onshore natural gas processing plant, which removes water vapour and natural gas liquids such as propane, butane and pentanes. The liquids go to another plant for separation, storage and marketing. The dry natural gas from the processing plant is compressed and shipped by pipeline to industrial customers and natural gas distribution utilities in Atlantic Canada and the New England states.

Workers aboard the Rowan Gorilla V jackup platform. *Photo courtesy of Alex MacAulay/Ocean Resources.*

8 Supplementary information

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Web sites

The Centre for Energy portal (www.centreforenergy.com) provides further information about the petroleum industry in Canada, a glossary of industry terms, information about employment opportunities, and links to other sites including those of the offshore petroleum boards and the Geological Survey of Canada.

Additional sources include:

Arctic Institute of North America *www.ucalgary.ca/aina/*

British Columbia Offshore Oil and Gas Team *www.offshoreoilandgas.gov.bc.ca*

Canada – Nova Scotia Offshore Petroleum Board *www.cnsopb.ns.ca*

Canada – Newfoundland Offshore Petroleum Board *www.cnopb.nfnet.com*

Canadian Association of Petroleum Producers *www.capp.ca*

Environmental Studies Research Funds *www.esrfunds.org*

Hibernia Management and Development Company Ltd. *www.hibernia.ca*

National Energy Board *www.neb-one.gc.ca*

Natural Resources Canada Office of Energy Research and *Development www2.nrcan.gc.ca*

Petroleum Research Atlantic Canada *www.pr-ac.ca*

Royal Society of Canada *www.rsc.ca*

Sable Offshore Energy Inc. *www.soep.com*

Terra Nova Project *www.terranovaproject.com*

White Rose Oilfield Development *www.huskywhiterose.com*

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Tug and supply vessel towing iceberg, Seabase/Maersk

Workers handling a drill pipe, HMDC

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Page 18 Steps in Emergency Prevention Planning, courtesy of the Canadian Association of Petroleum Producers

Page 22 table: Environmental Assessment Review Process, courtesy of Canada-Nova Scotia Offshore Petroleum Board

Page 28 and 29 tables: Selected Significant Discoveries and Exploration Support Services, courtesy of Newfoundland Ocean Industries Association

Page 36 Hibernia drilling and production platform, courtesy of HMDC

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