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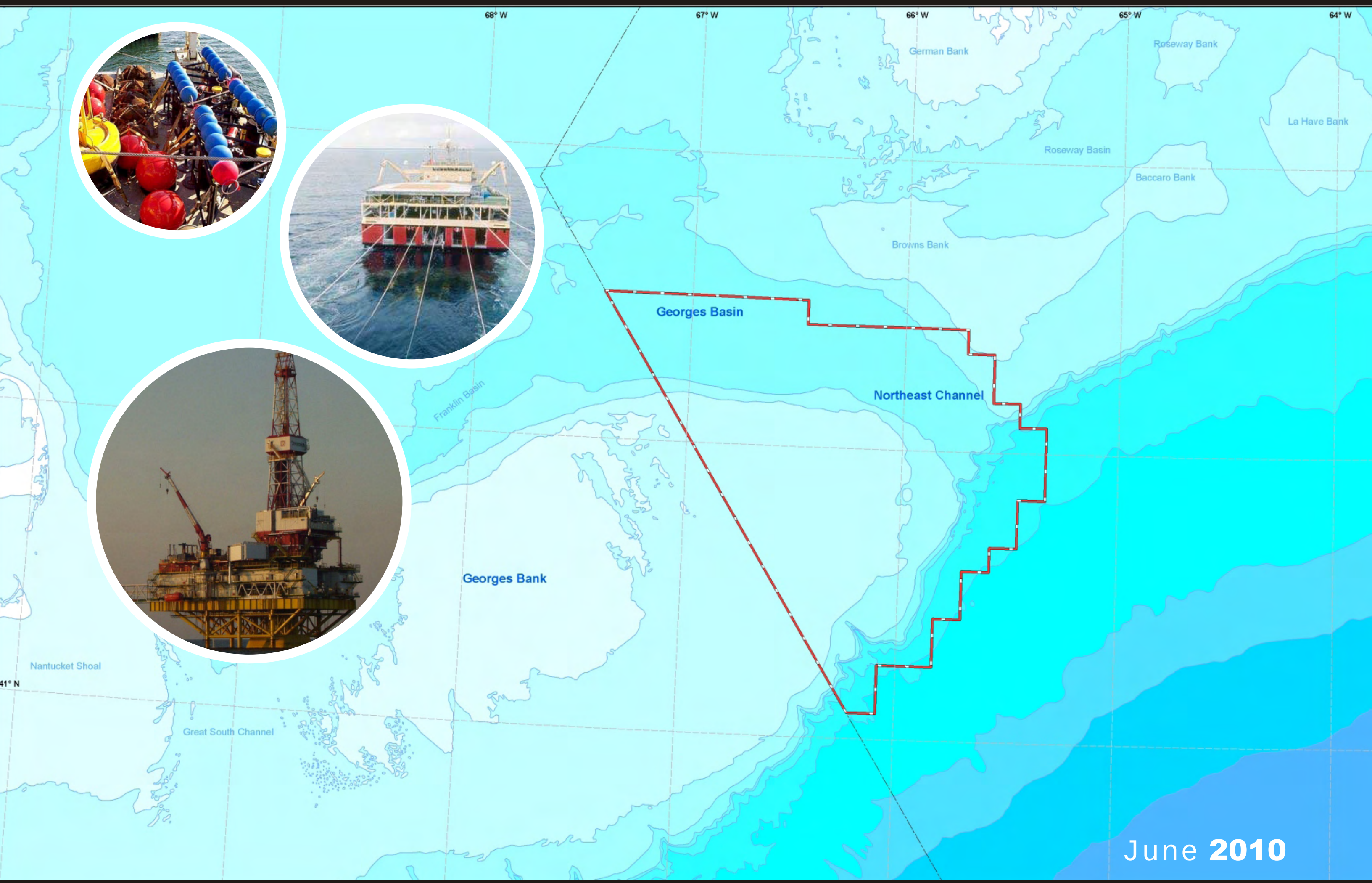

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A Preliminary Review of Existing Technologies and Their Mitigative Potential in Offshore Petroleum Developments

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Executive Summary

In 1988, the governments of Canada and Nova Scotia placed a moratorium on all petroleum activities on a portion of Georges Bank and adjacent areas under Canadian jurisdiction. The moratorium was then extended until 2012 following an independent panel review in 1999. This important regulatory decision was based on the most current information available at the time. Recently, the federal and provincial governments have launched independent science and technical reviews of Georges Bank and potential effects of oil and gas activities. These reviews are intended to update government decision-makers on the current state of knowledge on the science and issues that led to the 1999 Panel's recommendation to extend the moratorium.

In March 2008, the Nova Scotia Department of Energy provided the Offshore Energy Environmental Research Association (OEER) with a grant to support research on matters specific to Georges Bank. The mission of OEER is to foster research and development related to offshore petroleum and renewable energy resources and their interaction with the marine environment. Under this mandate, OEER has contracted Stantec Consulting Ltd. (Stantec) to conduct an assessment of technologies and practices in offshore exploration, drilling and production that have been developed or are emerging since the 1999 Georges Bank Panel Review. Building on the risks identified in the 1999 Georges Bank Review Panel Report and reference documents, these technologies and practices are examined in terms of their suitability for application in the Georges Bank area.

Recent publications, conference proceedings, environmental assessments, environmental effects monitoring studies, regulations, policies, best practices and discussions with technical experts pertaining to Georges Bank and/or technology in the offshore petroleum sector from, but not limited to, Fisheries Oceans Canada (DFO), the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB), Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), petroleum and offshore research institutes, associations, government agencies in Canada and in other jurisdictions have been used in this review to characterize the technological advances, including progress in mitigation of potential effects.

A summary of the issues raised in the Panel Report with respect to technological advances in seismic exploration, exploration drilling and petroleum production technologies is provided in Table E.1. Residual issues which remain in spite of (or in some cases originate from) these technological updates are also presented. The majority of these residual issues are not unique to Georges Bank, rather they are issues facing offshore petroleum projects globally. Table E.1 also presents research recommendations which could serve to further advance new technologies and practices in offshore petroleum developments. The majority of these recommendations are not specific to Georges Bank, but are presented here to help provide context to the current state of knowledge on those issues.

In summary, a considerable amount of technological innovation has occurred in the offshore oil and gas sector worldwide over the last ten years. The last decade has brought considerable oil and gas experience to Atlantic Canada in the form of exploration and production activities, none of which, based on the results of numerous environmental effects monitoring, have demonstrated population level effects to the marine ecosystem, or on species at risk and their critical habitat. Although the key issues identified by the 1999 Review Panel remain relevant ten years later, these issues identified in the 1999 Review Panel report could be reasonably mitigated due to advances in scientific knowledge, mitigation and regulatory requirements in addition to technological advances. It is important to note that it is not realistic to assume that all risks can be mitigated by technological advances alone. As best available technology continues to evolve, improvements in regulatory requirements and research and development in the context of environmental effects and mitigation also serve to minimize risks and issues of concern.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Seismic Surveys	• Opposing perspectives on risk of seismic surveys and level of information required to determine risk. • Key issues included potential physical effects of seismic energy on fish and fish larvae; potential effects on fish behavior; potential effects on marine mammals; and effects on access and crowding. • Seismic exploration vessels will disrupt fishing patterns and can negatively affect catchability of groundfish. • The presence of a safe navigation area would disrupt fishing activities and potentially lead to overcrowding in other areas.	• Innovations in alternative sound sources such as vibroseis are taking place but are not sufficiently developed for industrial application. • Airguns will likely remain the standard energy source for the seismic industry in near future (~5-10 years). • Seabed logging (SBL) surveys are an emerging technology which relies on airguns as the sound source. • Electromagnetic (EM) technology complements acoustic type surveys; however, this technology is still developing. • 3D seismic programs have become common practice by the industry to improve drilling success. • Large streamer arrays used in 3D seismic programs may impede the maneuverability of the seismic vessel and result in exclusion of other vessel activities in the area.	• There are potential sublethal effects on individual fish in the immediate vicinity of the seismic airgun array. • Alternatives to air guns have not been subject to as rigourous environmental review and therefore their effects are less understood. • The use of coil surveys and SBL surveys may, in some instances, provide a method to alleviate some of the access and crowding issues; however, there will need to be cooperation between resource users.	• Conduct detailed health evaluations of key individual fish and benthic invertebrate species exposed to seismic-level noise pressures (Hurley 2009). • Conduct pilot study and EEM for use of alternative energy sources to airguns. • Conduct research and stakeholder consultation comparing access issues between traditional seismic survey and coil surveys.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Drilling (Muds and Cuttings)	• Two basic types of drilling muds: water-based (WBM) and oil-based (OBM). Synthetic-based mud (SBM) is new and not widely used due to cost. • Laboratory experiments suggest sublethal effects of bentonite and barite on scallops could be experienced up to 40 km from discharge point. • Dispersion of drilling mud is not fully understood. • Probability of significant harmful effects from disposal of drilling discharges near Georges Bank cannot be discounted.	• WBM and SBM are used for offshore drilling in Atlantic Canada; OBM is not used. • The revised Offshore Waste Treatment Guidelines (OWTG) require concentration of 6.9 g/100 g or less oil on wet solids. • There are limited new technologies available which may be applied to the treatment of cuttings. • Development of risk assessment models, coupling transport models with biological effects models provides greater understanding of fate and effect of drilling discharges. • In some locations, mud and cuttings have been re-injected into the geological formation for disposal during multi-well development drilling. • Directional drilling can provide exploration into geological formations located beneath areas of sensitive or important marine habitat.	• Zero harmful discharge practices are not widely understood and are costly. • Alternative treatment methods require additional testing before they are likely to be considered commercially viable.	• Investigate applicability and cost of zero harmful discharge practices in Atlantic Canada.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Production (Produced Water)	• Naturally occurring contaminants present in formation and produced water in high concentrations can be toxic to marine species including important commercial species on Georges Bank.	• Continuous revision of the regulations and industry guidelines has taken place since 1999 which incorporate the use of new technologies in production operations and promote the concept of "best available technology". • Re-injection into the geological formation has developed as a method for disposing of produced water and waste gases which require disposal. • Fate and transport models have been developed which improve understanding and predictability of produced water movement and related effects. Focus is now on identifying contaminants of concern in produced water discharges. • Treatment technologies have been developed which reduce harmful discharges in produced water. One such technology has been successfully applied in the SOEP project.	• Re-injection wells for waste disposal (*e.g.*, produced water) are expensive to install and operate. Alternative disposal methods are required during maintenance and downtime. • Dilution is usually very rapid, making it very challenging to monitor toxicity after release to ocean.	• Explore solutions for reducing costs associated with installing and operating disposal wells and technical solution to avoiding the need of alternative disposal during maintenance and downtime. • Continue development of chronic toxicity studies to support development of cost-effective and sensitive monitoring protocols for regulatory use in EEM programs. • Continue research on identifying contaminants of concern in produced water streams.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Air Emissions	• Natural gas can be seen as a useful transition fuel away from coal and oil although it still results in greenhouse gas emissions.	• Updated OWTG include reporting requirements for GHG emissions and volatile organic compounds. • Flaring is a safety feature which reduces VOC emissions in event of safety-related trigger. • Techniques to minimize greenhouse gas emissions include carbon removal (*e.g.*, use of chemical stripping agents to absorb and desorb the carbon dioxide from the exhaust) and carbon capture (*e.g.*, injection to disposal well). • The recent Deep Panuke Project involves capturing and injecting CO_2 and H_2S into a deep aquifer disposal well thereby reducing GHG and atmospheric emissions.	• Carbon removal and capture technology requires further research for offshore application. • No alternative to fossil fuels is presently available for operating power systems on offshore platforms.	• Conduct research on offshore application of carbon removal and capture technology, including review of Deep Panuke injection of waste gas into reservoir. • Explore alternative energy sources for offshore use.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Petroleum Transportation (Pipelines and Tankers)	• Participants expressed concerns about damage from laying pipelines and loss of fishing access, although this issue was not given a lot of attention since production and transportation were not the focus of the panel review.	• Canadian and international standards for oil tankers are phasing out the use of single hulled vessel and older vessel types in favour of double hulled tankers. There has been a significant reduction in tanker accidents in the past thirty years. • Multibeam and other survey methods provide significant improvements in seabed mapping which reduce risks in selecting subsea systems locations and pipeline routes to avoid unstable topography and challenging geological formation. • Improved seabed mapping capabilities will improve pipeline routing to avoid challenging geologic formations and assess areas of sensitive biological habitat.	• Interpretation of multibeam data for Georges Bank would be required to refine habitat mapping and inform site selection to avoid sensitive habitats and geological risks.	• Continue work on interpretation of multibeam data to identify sensitive benthic habitats and geological risks.

Table E.1 Summary of Residual Issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Accidental Events	• Blowouts and spills could result in contamination of the marine environment and damage to marine populations.	• Training and qualification standards for offshore personnel have been developed and implemented by the Industry to improve operations and safety. • Annual spillage from exploration, production, and transportation has decreased dramatically due to improved technology and practices (API 2009; CNSOPB; C-NLOPB; ITOPF 2008). In particular, annual spillage from exploration and production has decreased from 30,400 bbl/year between 1969 -1977 to 3,900 bbl/year between 1998-2007 (API 2009). • Production oil spillage accounts for less than 0.9% of amount released from natural seeps (9,938 bbls vs 1,123,000 bbls from seeps annually from 1998 to 2007) (API 2009). • Fate and effect models are being continuously improved and can be used to support risk assessment studies, contingency planning, and clean-up operations.	• In spite of technological advances, the risk of a spill, albeit remote, will always remain. • Spill response measures are site and project-specific. Ongoing research and learnings from other spill events will serve to inform decision making.	• Develop and validate oil spill countermeasures for use on sensitive habitats such as Georges Bank. • Develop acceptable endpoints for clean up (*i.e.*, how clean is clean?).

Preface and Acknowledgements

The Study Team wishes to thank Brian Todd and Vladimir Kostylev of the Geological Survey of Canada, Eric Theriault of the Canada-Nova Scotia Offshore Petroleum Board, and Dave Burley of the Canada-Newfoundland and Labrador Offshore Petroleum Board, for providing access to technical information during the course of this study.

The Study Team would like to acknowledge that Fisheries and Oceans Canada is currently undertaking a science review of Georges Bank. The review consists of two documents, the first authored by Kennedy *et al.*, titled "The Marine Ecosystem of Georges Bank, Nova Scotia: Consideration of the Potential Interactions Associated with Offshore Petroleum Activities. Canadian Science Advisory Secretariat. CSA Working Paper 2010/04. Draft Report, February 2010" and the second authored by Lee *et al.*, titled "Environmental Impacts of Exploration and Production: Consideration of the Potential Interactions Associated with Offshore Petroleum Activities. Canadian Science Advisory Secretariat. CSA Working Paper 2010/05. Draft Report, February 2010". The Study Team acknowledges the reports are in a public review process and have not yet been published.

This report was prepared for the Offshore Energy Environmental Research Association by Stantec Consulting Ltd. with contributions by Gordon Fader and Cal Ross. Key Study Team members included: Tom Windeyer, BA; Virginia Soehl, MRM; Michael Peck, P.Eng.; and Heather Giddens, MES. The Report was senior reviewed by Earle Hickey, M.Sc., and Steve Fudge, M.Sc.

Acronyms

AUV	Autonomous Underwater Vehicle
BBLT	Benthic Boundary Layer Transport
BMP	Best Management Practice
BOP	Blowout Preventer
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CALM	Catenary Anchor Leg Mooring
CAODC	Canadian Association of Oilwell Drilling Contractors
CAPP	Canadian Association of Petroleum Producers
CCGOC	Canadian Coast Guard Operations Centre
COOGER	Centre for Offshore Oil, Gas and Energy Research
CEAA	*Canadian Environmental Assessment Act*
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEPA	*Canadian Environmental Protection Act*
CHARM	Chemical Hazard and Risk Management
C-NLOPB	Canada–Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CO_2	Carbon Dioxide
COPAN	Cohasset-Panuke
CRI	Cuttings Re-Injection
CSEM	Controlled-Source Electromagnetic
DA	Dragged Arrays
DFO	Fisheries and Oceans Canada
DGF	Dissolved Gas Floatation
DREAM	Dose-Related Risk and Effect Assessment Model
DSSPROWM	Decision Support System for Produced Water Management
EA	Environmental Assessment
EC	Environment Canada
ECRC	East Coast Response Corporation
ED	Electrodialysis
EEM	Environmental Effects Monitoring
EM	Electromagnetic
EMOBM	Enhanced Mineral Oil-Based Mud
EOR	Enhanced Oil Recovery
ESRF	Environmental Studies Research Fund
G&G	Geological & Geophysical
GHG	Greenhouse Gas
GPS	Global Positioning System

H_2S	Hydrogen Sulphide
HED	Horizontal Electrical Dipole
IGF	Induced Gas Floatation
MEG	Monoethylene Glycol
MMO	Marine Mammal Observer
MMS	Minerals Management Service
MODU	Mobile Offshore Drilling Unit
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MPPE	Macro-Porous Polymer Extraction
M&NP	Maritimes and Northeast Pipeline
NAZ	Narrow Azimuth Survey
NEB	National Energy Board
NEC	No Effect Concentration
NETL	National Energy Technology Laboratory
NGL	Natural Gas Liquids
NOI	Notice of Intent
NORM	Naturally Occurring Radioactive Material
OBC	Ocean Bottom Cable
OBM	Oil-Based Mud
OBS	Ocean Bottom Seismometer
OCNS	Offshore Chemical Notification Scheme
OCS	Outer Continental Shelf
OEER	Offshore Energy Environmental Research Association
OETR	Offshore Energy Technical Research Association
OFT	Offshore Fire Team
OGP	Association of Oil & Gas Producer
OSCAR	Oil Spill Contingency and Response
OSPAR	Oslo-Paris Commission
OSRR	Oil Spill Response Research Program
OWM	Oil Weathering Model
OWTG	Offshore Waste Treatment Guidelines
PEC	Predicted Environmental Concentration
PEIS	Programmatic Environmental Impact Assessment Statement
PLONOR	Pose Little or No Risk to the Environment
POCIS	Polar Organic Chemical Integrative Sampler
PROTEUS	Pollution Risk Offshore Technical Evaluation System
PWMIS	Produced Water Management Information System
PWRI	Produced Water Re-Injection
RAZ	Rich Azimuth Survey
REET	Regional Environmental Emergencies Team

ROC	Retention On Cuttings
ROV	Remote Operated Vehicle
SBL	Seabed Logging
SBM	Synthetic-Based Drilling Mud
SINTEF	Stiftelsen for Industriell og Teknisk Forskning
SOC	Synthetic On Cuttings
SOEP	Sable Offshore Energy Project
SPMD	Semi-Permeable Membrane Devices
SWD	Seismic While Drilling
TA&R	Technology Assessment & Research
TCC	Thermo-mechanical Cuttings Cleaner
TDG	Transportation of Dangerous Goods
TEM	Transient Electromagnetic
US	United States
VLCC	Very Large Crude Carrier
VOC	Volatile Organic Compound
VSP	Vertical Seismic Profiling
WAZ	Wide Azimuth Survey
WBM	Water-Based Drilling Mud
WHMIS	Workplace Hazardous Materials Information Systems

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1.0 Introduction

1.1 STUDY PURPOSE AND OBJECTIVES

In 1988, the governments of Canada and Nova Scotia placed a moratorium on petroleum activities on a portion of Georges Bank and adjacent areas under Canadian jurisdiction. Following an independent panel review in 1999, the moratorium was extended until 2012 (NRCan and NSPD 1999). This important regulatory decision was based on the most current information available at the time. Recently, the federal and provincial governments have launched independent science and technical reviews of Georges Bank and potential effects of oil and gas activities. These reviews are intended to update government decision-makers on the current state of knowledge on the science and issues that led to the 1999 Panel's recommendation to extend the moratorium.

Indeed, since 1999, there has been additional scientific research on the Georges Bank ecosystem, as well as numerous developments in technology, technical procedures and practices employed by the offshore petroleum industry in Atlantic Canada as well as other jurisdictions, which could provide guidance on the efficacy of existing and emerging technologies for consideration on Georges Bank.

The nature and priority of environmental concerns has also changed over this 10-year period, with issues surrounding growing global energy demand and heightened environmental awareness coming to the forefront. New developments in scientific and technological knowledge coupled with evolving environmental and socio-economic conditions provide the background for an opportunity to reassess the risks of petroleum exploration and development on Georges Bank. The purpose of this report is to research technologies and practices in offshore exploration, drilling and production that have been developed or are emerging since the 1999 Georges Bank review. Specifically, the study evaluates the reliability of the technologies and practices and their effectiveness in assuring that environmental risks are adequately addressed and mitigated. Possible areas of research that may be required to better understand the potential effects of new or emerging technologies/practices and if/how they may or may not be suitable for application in the Georges Bank area are also discussed (refer to Appendix A for Study Terms of Reference and Appendix B for concordance table).

A companion report has also been prepared by Stantec Consulting Ltd., under separate cover, to research key environmental and socio-economic issues relating to Georges Bank that have emerged since the 1999 Georges Bank Review Panel Report and to assess the current state of knowledge. These reports will be used by the Government of Nova Scotia to help determine whether a public review process of the moratorium on petroleum activities on Georges Bank is warranted prior to a decision in 2012.

1.2 GEORGES BANK OVERVIEW AND BACKGROUND TO MORATORIUM

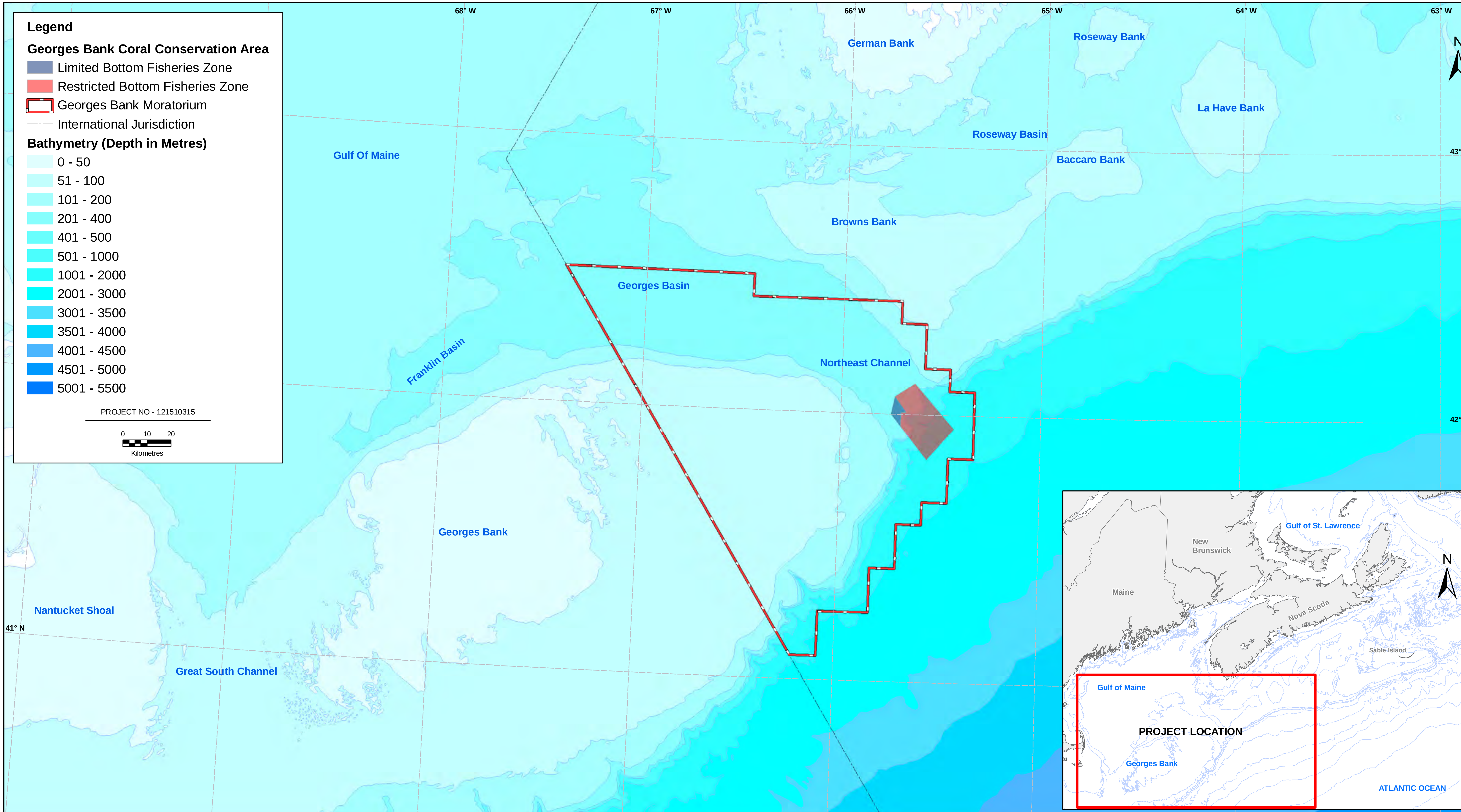
Georges Bank is located along the continental shelf of Eastern North America between the southern tip of Nova Scotia and Cape Cod, Massachusetts. The Bank is a biologically productive ecosystem that supports important commercial fisheries and provides habitat to a wide range of marine fish, mammals, corals, and other organisms. Georges Bank represents an important marine ecosystem for Canada and the province of Nova Scotia, and has also been an area of interest for petroleum exploration since the 1960s.

In 1988, a moratorium was placed on offshore petroleum activities on the Canadian portion of Georges Bank until the year 2000. The Canadian moratorium covers an area of 15,000 km^2 which includes the Canadian portion of Georges Bank (7,000 km^2) and extends to cover most of the Northeast Channel (Figure 1.1).

This moratorium decision was primarily driven by concerned local fishing interests and residents. Based on recommendations made by an independent review panel, the Minister of the Nova Scotia Petroleum Directorate and the Minister of Natural Resources Canada announced on December 22, 1999, that the Georges Bank moratorium would be extended until December 31, 2012. At the time the moratorium was enacted, Texaco, BP-Amoco and Chevron held exploration leases that were suspended but have remained in place over the period of the moratorium.

In their 1999 Report, the Georges Bank Review Panel identified knowledge gaps on the potential environmental effects of exploration and production activities, which made it challenging for the Panel to assess the environmental and socio-economic risks of petroleum development. The Panel therefore recommended an extension to the moratorium.

In 1984, the United States Congress enacted a moratorium on petroleum exploration over the U. S. portion of Georges Bank. In 1988, this area was enlarged. The US moratorium was extended twice, once until 2002 and then until 2012 by executive order, without a public review process, unlike that held in Canada (Shaw *et al.* 2000). Beginning in 1982, the United States Congress restricted more and more offshore areas through annual appropriations. At no time, was a law passed to permanently put these areas out of reach from exploration; these appropriations had to be renewed annually. In 2008, President Bush lifted an executive order restricting offshore drilling and the US Congress allowed a 27-year-old ban on most offshore oil and gas drilling to expire, thereby opening up the US outer continental shelf for petroleum exploration. Since then, bills have been introduced in the House of Representatives and Senate that would serve to protect Georges Bank from exploration activities, but none have become law. In March 2010, President Obama released a five-year drilling plan for the Outer Continental Shelf (OCS) that excluded any new oil and gas leasing activities in the north Atlantic, effectively reinstating the presidential ban on drilling on Georges Bank.



DATE: 16/02/2010	Georges Bank	FIGURE NO.: **Figure 1.1**
PREPARED BY: G. Mesheau		
CLIENT LOGO	**PROJECT LOCATION**	Stantec

Various seismic surveys were conducted off the US east coast including the US portion of Georges Bank between 1966 and 1990. In 1979, Lease Sale 42 included exploration blocks on the US portion of the bank (MMS 2009a). Associated with this lease, seismic surveys were conducted in two phases with 64,400 line km of seismic shot from 1974 to 1977 and approximately 53,000 line km from 1981 to 1982 during exploration drilling (Edson *et al.* 2000). The area covered in these seismic surveys, which were conducted prior to the settlement of the Canada-US border dispute (Oct.17, 1984), includes a portion of the Canadian Georges Bank. Ten exploration wells were drilled in the US North Atlantic area on the US portion of Georges Bank under this lease sale to evaluate the stratigraphy and hydrocarbon potential of the area. Eight of these wells were drilled for petroleum exploration and two wells were Continental Offshore Stratigraphic Test (COST) wells (MMS 2009a).

In 2009, the US Minerals Management Service (MMS) released a Notice of Intent (NOI) to "Prepare a Programmatic Environmental Impact Assessment Statement (PEIS)" and Call for Interest of Future Industry Geological and Geophysical (G&G) Activity on the Atlantic OCS" (MMS 2009b). This initiative is in response to inquiries by the Oil and Gas Sector on potential resource exploration on the US outer continental shelf (OCS). One of the purposes of the PEIS is to assess acoustic impacts on the marine environment from G&G activities (MMS 2009b). In January 2010, the US Interior Secretary announced a review of applications to conduct seismic programs on the Atlantic Continental Shelf (Oil Daily, January 26, 2010). Such seismic programs are subject to environmental review, which if passed, could initiate seismic programs as the first phase of hydrocarbon exploration on the east coast of the US.

The Offshore Energy Technical Research Association (OETR) is currently undertaking a project to reprocess and re-examine the original seismic data collected on Georges Bank. This project includes the transcription of original nine track field data tapes into a modern format which will improve quality of the signals and reflectors to improve the resolution of the stratigraphy. These improvements will enhance the ability of resource scientists to re-evaluate the hydrocarbon reserve estimates on Georges Bank (OETR 2010).

The potential presence of petroleum hydrocarbon resources on Georges Bank is based on the interpretation of the US Georges Bank seismic and drilling programs with reference to the geology of the adjacent Scotian Basin and the reserves discovered there. MMS suggests deeper drilling (20,000 feet) may be required to detect over-pressured gas or condensate deposits (Edson *et al.* 2000). No exploration drilling has been conducted on the Canadian side of Georges Bank. Potential petroleum hydrocarbon reserves on the Canadian portion of Georges Bank were estimated to be 1.1 bbls of oil and 5.3 tcf of natural gas (Proctor *et al.* 1984).

1.3 STUDY APPROACH AND REPORT ORGANIZATION

The purpose of the report is to revisit the decision factors that led to the 1999 Panel's recommendation to extend the moratorium and reassess these factors in light of existing and emerging technologies for offshore petroleum exploration and production activities. A review of technical issues discussed in the 1999 Panel Report highlighted areas of concern and/or uncertainty (*e.g.*, lack of knowledge identified around an environmental effect). For the activities associated with each of the following offshore petroleum exploration and production activities, practices and existing and emerging technologies used in Nova Scotia, Canada and other jurisdictions were reviewed: seismic exploration, exploration drilling and production, and accidents and spills. Regulatory reports (*e.g.,* environmental assessments, comprehensive study reviews) filed with the appropriate regulatory body for projects in the offshore of Nova Scotia, other areas in Canada and other jurisdictions were reviewed for indications of changes in technology. Technical conference summaries and technical reports, mainly focused on drilling and seismic technology were also gathered and reviewed.

The following describes the report organization:

- **Section 1** identifies the purpose of the study and objectives and describes an overview of Georges Bank and background to the moratorium.
- **Section 2** provides a detailed review of the key issues identified in the 1999 Georges Bank Review Panel Report with respect to: seismic exploration, exploration drilling (drill muds and cuttings), offshore production (produced water, petroleum transportation, air emissions) and accidental events. The evolution and status of existing and emerging technologies in each of these areas of offshore activity is examined. The implications of these technologies are discussed in terms of their relevance to issues raised in the Panel Report.
- **Section 3** provides a summary and discussion of the residual issues, in consideration of advances in technology and progress in mitigation, and the implications for future consideration in a sensitive area like Georges Bank. Requirements for additional studies and research programs which would assist in addressing residual issues are also outlined.
- **Section 4** lists the references and personal communications cited throughout the report.
- **Appendix A** and **Appendix B** include the OEER scope of work for the study as well as a concordance table linking report sections to the scope of work.
- **Appendix C** describes the regulatory framework that governs offshore petroleum activities and relevant environmental management frameworks, focusing on changes to the regulatory context since the 1999 Panel Report.

2.0 Assessment of Technologies and Practices

Seismic surveys and exploration drilling are used to delineate geological features under the seabed in order to determine hydrocarbon potential. Petroleum development and production follow the successful completion of seismic and drilling exploration programs which have identified a suitable and economically viable reservoir for production. The development phase would involve the design and construction of production facilities and transportation options (*e.g.*, pipeline). The production phase involves extraction, processing, and transportation of petroleum product. At the end of the production phase, the facilities are decommissioned and abandoned.

Each of these phases involves different technologies and procedures and is governed by regulations and guidelines to address environmental, health and safety issues (refer to Appendix C for an overview of the regulatory framework for offshore petroleum activities). Each phase of offshore petroleum activity presents its own key environmental issues for consideration, most of which are not particularly unique to a specific project, although the significance of effects may vary depending on various project and receiving environment characteristics.

Many of the issues and concerns identified by the Georges Bank Review Panel in 1999 are similar to the issues and concerns being raised in other marine environments where important ecosystems, fisheries and development of hydrocarbon resources overlap. The technologies and activities of offshore seismic exploration, exploration drilling and petroleum production around the world and in the waters off Eastern Canada have been subject to continuous developments and change prior to and since the release of the Georges Bank Panel Review Report in 1999. Many of the changes or adaptations have been initiated as a result of increasingly stringent regulatory requirements and improved scientific understanding of the issues.

These key issues are discussed below in the context of existing and emerging technologies and their relevance to Georges Bank should petroleum activities be permitted to occur within the moratorium area. For the ease of the reader and to minimize repetitiveness, the discussion of existing and emerging technologies although organized by phase, are primarily focused on key issues that are associated with that phase.

2.1 SEISMIC EXPLORATION

Seismic exploration for petroleum resources uses the reflection of sound pulses to characterize the various layers and structures of the Earth's crust to identify formations which may hold petroleum reserves. Seismic technology has been in use in the petroleum exploration sector for many decades. Over that time, there has been continuous development in the fields of petroleum geology and geophysics and in the equipment used such as the sound sources, data processing and navigation. These advancements have improved the resolution and accuracy of seismic data and aided the industry in detecting hydrocarbon reserves. The scientific principle of reflecting sound energy from the different strata in the geological formation remains a foundation for this industry.

Offshore seismic programs for locations such as Georges Bank are typically conducted by large (100 m length) special purpose seismic vessels which tow an array of sound sources (airguns or waterguns) and echo receivers (streamers with hydrophones) which record reflected sound frequencies (Figure 2.1). Navigation data is recorded to precisely identify the locations of the recorded information. The seismic vessel traverses in lines in a grid pattern across the project area towing this equipment which might extend up to five to eight km in length behind the ship. The data is recorded onboard the vessel and processed onshore using sophisticated computer technology and interpreted by petroleum geologists and geophysicists to assess likely locations for petroleum reserves.

There are currently three basic types of seismic surveys conducted in offshore petroleum exploration. These are:

- 2D seismic surveys which are conducted over large areas of the seabed to identify geological structures with potential petroleum hydrocarbon bearing formations;
- 3D seismic surveys which have a similar purpose to 2D seismic surveys but provide a much higher resolution of geological structures and therefore provide better information with respect to potential petroleum hydrocarbon bearing formations; and
- Geo-hazard site surveys which are used to identify seabed and shallow subsea hazards prior to exploration drilling.

There are functional similarities in the equipment used in these surveys; however, the scale and energy levels required for 2D and 3D seismic surveys is significantly greater than the equipment used in geo-hazard surveys of shallow seabed features.

Figure 2.1 Vessel Conducting a Seismic Program

2.1.1 Panel Comments

The 1999 Review Panel Report identified several concerns related to seismic exploration including:

- Potential physical effects of seismic energy on fish and fish larvae;
- Potential effects on fish behaviour;
- Potential effects on marine mammals; and
- Effects on access and crowding.

The Review Panel heard divergent perspectives regarding the effect of seismic surveying on fish and fish larvae. Some participants stated that seismic surveying should proceed because the risks are acceptable and others indicated that caution should be exercised because the risks are too high. The Panel identified a need for more comprehensive observations of the effects of seismic surveys on particular species of larvae on Georges Bank.

Concerns expressed about potential effects of seismic surveys on fish behavior were mainly focused on the extent by which catches might be reduced. Again, the Panel heard divergent perspectives regarding the potential effects of seismic surveys on fish behaviour –that an acceptable level of risk exists in terms of affecting fish behaviour and that the risk is too high. Participants did not present specific information or studies with respect to potential effects of seismic surveys on fish spawning behaviour or the behaviour of adult lobsters, scallops and pelagic fish. The Panel concluded that there is some credible evidence, which may be applicable to Georges Bank, of a “significant adverse effect of seismic on fish behaviour” (NRCan and NSPD 1999).

The 1999 Review Panel also commented on potential effects to marine mammals (relating to underwater seismic noise) and expressed uncertainty; both in terms of the mechanisms (pathways) of effect and overall risk to this group and key species at Georges Bank (*e.g.,* endangered north Atlantic right whale). Assertions of potential effects to marine mammals (auditory damage, long range detection, short and long-term avoidance) were generally described as unlikely, short-term, minor, and local; but were discussed with the caveats that evidence for (or studies on) most of these potential effects on species inhabiting Georges Bank was lacking. The Panel did not review, discuss, or recommend mitigation measures to reduce or eliminate the potential effects of seismic activity on marine mammals.

Effects on access and crowding were also considered, with the Panel acknowledging an overlapping demand for access in excess of the time and space available on Georges Bank. The Panel concluded, with no uncertainty, that seismic surveys in progress would cause some inconvenience and disruptions to the patterns of fishing.

2.1.2 Existing and Emerging Technologies

In recent years, the petroleum industry has focused more effort and resources into seismic surveys and information processing to identify prospects for drilling success. Development of the Scotian Shelf illustrates the industry’s requirements for seismic programs to support offshore exploration. Between 1960 and 2006, there has been approximately 401,000 line km of 2D seismic work shot on the Scotian Shelf. Of this total, approximately 68% or 271,250 km was conducted prior to 1985. The first 3D seismic program was conducted in 1985. Since then, 29,512 km^2 of 3D seismic has been completed on the Scotian Shelf with the highest level of activity in the period from 1999 to 2001. Also since 1985, an additional 129,700 line km of 2D seismic surveys have been completed (CNSOPB 2009).

Better understanding of the geological features where petroleum hydrocarbons are trapped increases the potential success of drilling programs and aids in determining reservoir capacity and project economics. The last decade has seen significant efforts to improve the quality of data acquisition and also to improve the interpretation of seismic records through the use of sophisticated computer modeling and visualization graphics. Although it is advances in survey methods and operations which require further analysis and understanding for the evaluation of activities on Georges Bank, the methods applied in interpreting the data also influence the level of effort required in the other aspects of exploration.

The technology used in seismic programs has advanced in the past decade and 3D seismic surveys now play a much larger role in petroleum exploration on a global scale. The quality of digital data collected has greatly improved and in most cases eliminates the need for repetitive mapping and results in a one-time pass over the seabed area. Although there are similarities in the equipment used in 2D and 3D seismic, 3D seismic programs require larger arrays of streamers. The focus of the environmental issues identified by the Panel, which remains today, is the energy emitted by airguns and the safe navigation area associated with large vessel surveys.

2.1.2.1 Data Acquisition

The techniques used to conduct deep seismic programs continue to evolve as petroleum producers attempt to better define complex geological structures where hydrocarbon reserves may occur. In the past decade, the industry has developed various seabed logging (SBL) techniques including Ocean Bottom Seismometer (OBS), Dragged Arrays (DA), Ocean Bottom Cables (OBC) and low frequency electromagnetics (EM) to enhance information on reservoirs (IAGC 2002). The technological developments using OBS, DA and OBC methods are intended to enhance the data collection and signal processing by sensing reflection and refraction of acoustic signals through the geological formation to an array of sensors in contact with or very near the seabed. Mounting the sensor array on the seafloor removes the influence of the water column on the acquired data. Typically, an airgun array towed by a surface vessel is used as the source of energy for these sensor systems.

EM systems differ from systems which utilize acoustic energy by measuring the electrical resistivity of geological strata to differentiate between layers (Rosten *et al.* 2003). This method, termed a controlled-source electromagnetic (CSEM) method uses a low frequency electromagnetic field (0.05 to 10 Hz) produced by a towed horizontal electrical dipole (HED) antenna and the detection of the refracted signals by EM sensors which have been placed on the seabed (Yuan *et al.* 2009). Danielson *et al.* (2003) describe the use of transient electromagnetic (TEM) and developments in the method and interpretation in the exploration for groundwater resources in Denmark. This research which has been conducted since the mid-1990s, adds to the body of knowledge related to EM methods and the interpretation of geological formations (Danielson *et al.* 2003).

Variations in resistivity can be used, for example, to determine the existence of potential hydrocarbon geological formations where refracted high resistivity values can define hydrocarbon-bearing strata as compared to low-resistivity strata containing high salinity fluids (Rosten *et al.* 2003). The EM method provides such differentiation where acoustic-based data is less definitive. Johansen *et al.* (2008) report that the target depths for EM surveys range from 200 m to 2500 m below the seabed. The data provided by EM surveys and interpretation methods are generally used to supplement 3D seismic data, may be used in conjunction with seismic data to enhance the understanding and interpretation of geological features and thus increase drilling success rates. Between 2006 and 2009, ExxonMobil and its partners conducted CSEM surveys in the Orphan Basin offshore Newfoundland (LGL 2009). This was the first time this technology has been used in Atlantic Canada, although ExxonMobil has used CSEM technology to supplement seismic data with success in West Africa, Brazil, Columbia and Norway (LGL 2006).

Further development of the technology and interpretation methods is required before the method becomes widely used in the offshore petroleum industry (Johansen *et al.* 2008). It is evident in the literature, that EM provides a promising future addition to the methods for offshore exploration, although it will most likely be used only in conjunction with seismic surveys and not as a stand-alone data acquisition method.

2.1.2.2 3D, 4D and 4C Seismic Surveys

3D seismic surveys provide geological data in close spaced sets (25 to 50 m) in three planes (two horizontal axes, x and y and the vertical axis, z). Computer analysis provides a means to project a detailed three-dimensional map of geological strata in order to interpret the reflected signals to identify features which are potential hydrocarbon-bearing formations (Davies *et al.* 2004).

4D seismic refers to the practice of conducting 3D surveys of existing production reserves over time to map the changes to the reservoir. By repeating 3D at regular intervals, the changes in the flow of hydrocarbon reserves within a formation can be determined. These surveys are used to enhance recovery as the reservoir changes with depletion (Davies *et al.* 2004, Rigzone 2010).

4C seismic surveys are a recent development by the industry to better identify gas and liquid formations within sedimentary rock formations. These surveys are conducted using multi-component sensor arrays and are the leading edge of seismic industry technology (Davies *et al.* 2004; Rigzone 2010).

2.1.2.3 Vertical Seismic and Seismic While Drilling

Vertical seismic profiling (VSP) is a procedure used during drilling operations to examine the geomorphology of the structure around the well. There are a number of VSP methods available which are used to correlate the geological formation found in the well bore with the formations predicted from surface seismic programs. In marine exploration, geophones are typically placed in the well and an acoustic source such as an airgun is used to produce an acoustic signal which reflects through the formation and is recorded by the geophones. This data can be correlated to existing seismic data and the geological information logged during drilling, thus providing more precise information on the geological formation and predicting the nature of the formation ahead of the drill. VSP can be used in conjunction with other wells in the field to provide information on geological structures between wells. VSP is a conventional technology used in exploration and development drilling phases of a development.

Seismic while drilling (SWD) is an emerging technology which uses the noise (vibration) generated at the drill bit in conjunction with seabed geophone receivers to generate seismic data in the immediate vicinity of the well. This technology enhances drilling information and improves characterization of the seabed seismic data by using real-time information essentially providing a method to "look" ahead of the drill bit and more accurately predict when formations and high pressure zones will be encountered. The technology has yet to receive wide application in the industry in part due to cost; however, it appears that there has been sufficient interest to maintain research and development programs amongst technology providers (SPE 2007).

Although seismic-related, these technologies would only be implemented as part of drilling operations.

2.1.2.4 Advanced Seismic Survey Methods

Traditional 2D marine seismic programs were conducted by a survey vessel sailing a series of straight parallel lines along one azimuth and a second series of tie lines at 90 degrees to form a grid pattern over the survey area. Initially, 3D seismic surveys followed a similar method and pattern but with greater and higher density coverage using wide streamer arrays, described as narrow azimuth surveys (NAZ). Recently 3D seismic surveys have adopted alternative survey methods to achieve improvements in data resolution by conducting multiple vessel surveys using two or more vessels towing airguns and streamers offset on parallel courses with additional seismic source vessels using airgun arrays between. This method is referred to as a wide azimuth (WAZ) survey. By using offset receivers, the reflected acoustic signals are collected from a wide range of angles which can provide better resolution of complex geological formations (Buia *et al.* 2008). This method has been expanded to cover several azimuths over the same project area and is referred to as a rich azimuth (RAZ) survey. Coupled with improved computer imagery and geo-science modeling, these techniques are intended to enhance the definition of complex geological formations and improve the results of exploration drilling.

The surveys described so far are laid out on a series of parallel lines. The survey vessel(s) approach the line on a fixed speed and course and maintain that speed and course (to the extent possible) until the end of the line is over shot by the streamer. The vessel must make a large sweeping 180 degree turn and shoot the next line in the opposite direction. During the turns, the seismic equipment is shut down and no data is collected. Given that these turns require much time; this has a significant influence on the time and costs for seismic data collection. WesternGeco has developed a survey method referred to as a "coil shooting" where a single 3D survey vessel follows constantly turning survey lines while shooting. The method applies steering devices on the streamers to maintain streamer separation and requires subsea acoustic positioning network to provide accurate locations of the streamers in the array (Buia *et al.* 2008). The received data is used to refine the analysis components of a reservoir to better define petroleum reserves and therefore are usually used at known reservoirs.

2.1.2.5 Sound Source Technology

With concerns over the issues related to sound energy sources in the marine environment, the petroleum industry and geophysical contractors have been looking for viable alternatives to airguns. Some researchers have examined the potential of marine vibrators as an alternative to airguns. Vibration methods are used on land-based seismic surveys and have replaced dynamite in many applications. These surveys are conducted by laying out lines of geophones at intervals along a transect which are connected to a recording system. A low frequency sound wave is induced into the geological formation using a vehicle mounted vibration source.

Researchers have experimented with seismic vibrators for shallow water coastal areas since the 1980s; however, it appears that there has been limited application of this technique. Marine vibrator systems (*e.g.,* marine vibroseis) have been tested in water depths ranging from about 1 to 380 m. The maximum usable water depth is a current limitation of these systems. It is believed that marine vibroseis could be used in water deeper than 380 m if multiple or larger sources of vibration are used (increasing the effective source level) or longer integration times are used. A separate study of the potential effects of marine vibroseis on marine life is currently being funded by the Joint Industry Program, Sound and Marine Life (www.iagc.org/en/art/758/).

Theriault *et al.* (2006) examined the differences in the waveforms generated from marine vibrators and typical equipment used in marine geophysics. They identifiy airguns as providing an “incoherent” waveform whereas a marine vibrator generates a “coherent” waveform. They conclude that the performance factors required by the research determine the selection of the equipment and that further research and development of sound energy sources is required. Bird (2003) suggests that a swept signal source as generated by a vibrator could have less environmental effects than impulse sources such as an airgun or explosive. Prototypes and limited production marine vibrators were developed in the 1980s and 1990s; however, these systems have not seen extensive development for deep water marine applications.

Several other alternatives to conventional seismic airguns have been identified. Electro-mechanical and petrol-driven acoustic projectors have shown large reductions (30 to more than 65 dB) in sound level above 100 Hz. Sound reduction at frequencies below 100 Hz is also possible through the use of alternative source signals and advanced cross-correlation processing procedures (published data shows a reduction on the order of 15 dB below 100 Hz). These systems are currently in development and are not likely to be commercially available in less than ten years.

Johnson *et al.* (2007) describe the use of an acoustic blanket which attenuates the acoustic pulse above a towed airgun array. This method was developed for applications where the airgun signature must be modified to attenuate the “ghost” signature created by reflection of the upper vertical sound pulse from the air/sea surface interface. This method has had limited application but appears to have been a successful method of altering airgun acoustic performance.

2.1.3 Relevance to Panel Comments

Although other sound sources, such as water guns and marine vibrators, have been designed and tested, airguns have evolved as the most important sound source for the industry for open water surveys for locations such as Georges Bank. Airguns are used in conventional 2D and 3D surveys as well as more advanced 4D and 4C seismic programs. Airguns are also used in SBL techniques such as OBS, DA and OBC. These survey methods are most often applied on known reservoirs to enhance reservoir knowledge.

There has not been a worldwide consensus regarding the environmental issues associated with airguns and their potential effects on fish, fish larvae, crustaceans and marine mammals. Some jurisdictions including Canada consider this is an environmental issue and have established codes of practice to mitigate potential effects. Numerous studies have been conducted offshore Nova Scotia (including monitoring of seismic surveys on the Scotian Shelf) to better understand the effects of seismic surveys on marine organisms (Stantec 2010). In general, however, effects of seismic noise on fish, shellfish and other pelagic marine invertebrates are expected to be low with no serious or long term harm at the population level (Stantec 2010).

Emerging technologies such as vibroseis and EM offer potential technologies for the future, although it is uncertain if these systems could ever be used to conduct stand-alone exploration geophysical surveys (*i.e.*, without the supplemental use of seismic data). Testing of alternative sound sources (*e.g.*, through use of field trials) should be accompanied by environmental effects monitoring in order to determine environmental acceptability (J.V. Young pers. comm. 2010).

The environmental assessment report filed in 2006 as part of the application for approval for the ExxonMobil CSEM survey in the Orphan Basin predicted no significant environmental effects from the project, particularly given the low frequency, short duration (few hours), small geographic extent (within 50 km^2) of exposure of energy, and reversibility of effects (LGL 2006). Monitoring conducted during the survey was similar to monitoring programs conducted for conventional seismic surveys (*i.e.*, marine mammal, seabird and sea turtle monitoring).

The state of technical alternatives indicates that, at least in the near term (*i.e.,* five years) vibroseis and other technologies will move from the conceptual design and prototype stages into operational systems. Emerging technologies such as vibroseis and EM, although undergoing development, are not yet sufficiently economic and reliable methods to replace the present airgun systems. Until there is a viable alternative, seismic survey technology will continue to rely on airguns as the primary sound source (J.V. Young pers. comm. 2010).

As such, in Canada and other jurisdictions, regulations and codes of practice have been established to mitigate potential effects from the acoustic energy generated by airguns and to avoid collisions with large marine species (Table 5 in Appendix C).

The size and complexity of exploration seismic operations has grown, particularly over the past 15 years. Access and crowding, particularly where 3D seismic programs are being conducted remains an issue due to the size of seismic arrays and constraints on survey vessel maneuverability and constraints on fishing due to the types of fishing gear which may be used on Georges Bank. A typical 3D seismic program can involve a safe navigation area around the seismic vessel which can be over 1 km wide and 6 to 10 km long and require unobstructed course lines which may be many kilometres long. Therefore, seismic programs and fishing activities tend to be mutually disruptive.

The use of coil surveys may provide a method of conducting surveys over more limited areas and over a shorter period than those using present survey methods. This method might allow seismic programs to be conducted concurrently with fishing activities in adjacent areas. As the use of coil shooting techniques becomes better developed, there may be a reduction in the time and area required to conduct surveys which could reduce potential effects on the accessibility to fishing grounds.

The future use and development of OBC to replace towed streamer arrays also offers the potential to reduce accessibility issues, at least on the surface. By removing the requirement for long, towed, streamer arrays, the surface seismic vessel operating an airgun array becomes much more maneuverable and therefore can work within a tighter survey area. However, the area on which the OBC is laid requires the exclusion of fishing vessels, particularly those using bottom gear. A review of available environmental plan summaries for OBC seismic surveys conducted offshore Australia (Octanex NL 2008; Apache Energy 2008) reveals similar environmental issues associated with conventional seismic surveys, including seismic effects on marine organisms and disruption to other marine users (*i.e.*, commercial fishers) but also adds disturbance to benthic habitats (rated as negligible effect) associated with the laying and recovery of cables on the seafloor.

Regardless of the method and technology used to capture seismic data, consultation and coordination of activities would be required to minimize effects on fishery activities.

2.2 EXPLORATION DRILLING

Exploration drilling for petroleum hydrocarbon exploration, if allowed to occur on Georges Bank, would likely use drill rigs and support services similar to those presently used on Sable Island Bank and the deeper regions of the adjacent Scotian Shelf. In shallow water, up to approximately 130 m, harsh environment jackup rigs designed for the weather conditions, sea state and bottom conditions around Nova Scotia would warrant consideration as a candidate rig. Jackup rigs have legs which extend to the seabed on which the working platform can be jacked up free from the sea surface (Figure 2.2). The use of jackup rigs may depend on presence of suitable seabed features.

In deeper water, such as along the shelf in the Northeast Channel to the east of Georges Bank, a semi-submersible rig would be more conducive to exploration drilling. A semi-submersible drill rig is a large platform floating on columns and pontoons which are below the influence of typical wave action providing a stable platform from which drilling can take place (Figure 2.3). In relatively shallow water, a semi-submersible may be anchored into position with an array of anchors on the seabed. In deep water, a dynamic positioning system is used to maintain the rig over the drill site using thrusters on the vessel's hull. The thrusters are operated by a computer system to counter any movements in the rig's position as detected by a combination of surface navigation (*e.g.,* GPS), acoustic positioning devices and a strain cable tethered to the seabed.

Figure 2.2 Gorilla Class Jackup Rig (courtesy of Rowan)

Figure 2.3 Semi-Submersible Eric Raude Floating at Anchor (courtesy of EnCana)

The key issue of concern related to exploration drilling is the disposal of drill muds and cuttings, which are therefore the focus of this discussion. The OWTG (NEB *et al.* 2002a) outline recommended practices and standards for the treatment and disposal of wastes from petroleum drilling and production operations in Canada's offshore areas, and for sampling and analysis of waste streams to ensure compliance with these standards (NEB *et al.* 2002a). These Guidelines are reviewed and updated approximately every five years and are currently under review by the National Energy Board (NEB), Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) and Canada-Newfoundland & Labrador Offshore Petroleum Board (C-NLOPB) with input from stakeholders. The key updates in the 2002 revision included a concentration limit of 6.9 g/100 g or less oil on wet drill solids.

At the time of the Georges Bank Panel Review, the 1996 version of the Guidelines were being used, which included a requirement of treatment of drill waste to reduce oil concentrations to 15 g/100 g or less of dry solids (NEB *et al.* 1996). Between the 1996 and 2002 versions of the Offshore Waste Treatment Guidelines, a 1% discharge limit was implemented in 2000. This 1% discharge limit resulted in operators “skipping and shipping” the drill waste to shore for land disposal. The limit was changed to 6.9% in 2002 based on an understanding of best available technology and environmental effects monitoring results which had demonstrated a lower impact level than previously assumed during environmental assessments of drilling projects.

2.2.1 Panel Comments

The 1999 Review Panel identified that there was uncertainty as to whether the discharge of muds and cuttings from a drilling rig on or near Georges Bank would have significant, harmful effects on the marine environment. Varying (and often contradicting) perspectives from the fishing industry, the petroleum industry and scientific researchers were presented. Key issues were related to the potential sub-lethal and chronic long-term effects of drilling wastes, as well as bioaccumulation. For example, it was identified by some presenters that even if water-based mud (WBM) and synthetic-based mud (SBM) were used, the potential exists for smothering of benthic organisms; however, other sources (*e.g.*, scientific research by Cranford *et al.* 1998) found the effects to be localized. Data gaps were also discussed, such as the need for chronic toxicity data on the many additives in drilling muds, as well as the need to investigate the potential lethal and sub-lethal effects on marine resources other than scallops, lobster and haddock, and the overall ecosystem structure and function on Georges Bank.

The 1999 Review Panel commented that presentations from the petroleum industry were based on an assumption that used drill muds and cuttings would be discharged from the rig to the marine environment, but the possibility was raised that they could be disposed of remotely either offshore or onshore. This was not a specific regulatory requirement in 1999, nor is it now; however, as noted below, in the past decade considerable advancements have been made in offshore treatment and disposal, cuttings re-injection and transporting discharges to shore for disposal.

2.2.2 Existing and Emerging Technologies

Each hydrocarbon-bearing reservoir is different and therefore treatment technologies for exploration and production facilities must provide technologies and engineering solutions to be designed to address specific issues encountered. Some discoveries have primarily gas and others primarily oil. The composition of the hydrocarbons can be very different as well as the reservoir hydrocarbon-bearing structure. As a result, each reservoir requires site-specific exploration and drilling procedures to minimize waste and protect the marine environment. Various technologies for exploration drilling are discussed below.

2.2.2.1 Directional and Extended-Reach Drilling

Directional drilling is the ability to steer the drill-stem and bit to a desired bottom-hole location. Directional wells are initially drilled straight down to a pre-determined depth and then gradually curved at one or more different points (side tracked) to penetrate one or more given target reservoirs. Directional drilling allows for multiple production and injection wells to be drilled from a single offshore drilling unit thus minimizing the cost and the surface impact. It may also be used to reach a target located beneath an environmentally sensitive area. Directional drilling has been proposed to permit exploration under Alaska's Arctic National Wildlife Refuge from a location outside the refuge boundaries (Hebert 2009)

The limitations of directional drilling are primarily dependent upon maximum hole angle, rate of angle change, true vertical depth, and torque or friction considerations. The type of geology or rock that is to be drilled influences the friction considerations and some formations tend to collapse and cause the drill string to get stuck. The rule of thumb in the mid-1990s was that the horizontal displacement of the bottom hole location should be twice the vertical depth of the well. Currently, new drilling records are commonly being set and the results are three or four times vertical depth. Depth depends on the reservoir and the drill plan trajectory. Directional drilling and side tracks have been used on the Scotian Shelf.

The main benefit of directional drilling is that the drilling rig can remain stationary and various reservoir targets can be accessed from the one location. The wells still get drilled so amount of wastes generated does not change, but the wastes are concentrated in one location versus several. This can be a benefit or a detractor depending on the environmental sensitivity of the location. The total drilled length of the well is almost certainly longer with directional wells; however, there are fewer satellite platforms or in-field subsea flowlines, both of which have an environmental footprint. All of these issues would need to be quantified to decide on the best approach when developing a new field.

2.2.2.2 Rigless Drilling

Rigless Drilling is a term often used in association with the refurbishment and repairing of existing marine production wells using a seafloor mounted cable rig. A number of firms provide these services to the petroleum industry and are contracted to conduct work-overs or other well maintenance services to enhance or extend production.

Badger Explorer ASA (Badger) of Norway has patented and is developing an internally powered drilling device which will core into the bottom sediments to conduct investigations for petroleum hydrocarbon resources. The concept will allow exploration of the seabed sediments without the cost and complexity of a drilling platform (http://www.bxpl.com).

Badger is presently proposing to conduct tests of a prototype with the goal of self-burial as the first stage in the proof of concept. The project has received support from ExxonMobil, Shell and Statoil. This technology may offer environmental and cost advantages over conventional surface drilling rig for exploring the near surface sediments and conducting geotechnical investigations. The concept will not likely be available in a commercial form for a number of years.

2.2.2.3 Zero Harmful Discharge Drilling

The claim of “zero discharge drilling” has been made by some drillers/operators in some instances; however, it is better described as zero harmful discharge to the sea. Even if a drill program “skipped and shipped” all discharges to shore for disposal, discharges to the atmosphere via diesel engines, flaring, or cold venting remain.

An example of zero harmful discharge to the sea occurred for the Snohvit field in the Norwegian area of the Barents Sea by Statoil where the drilling company and operator reviewed and ranked all the chemicals used in the drilling process as to toxicity and evaluated options to use non-toxic substitutes. Initially there was to be no discharge of drill cuttings and mud (the exception was top hole section). In the end, the cuttings with WBMs were allowed to be discharged as no better available technology existed (2003/2004).Some highlights of the zero harmful discharge initiative were as follows:

- Zero discharge of produced water;
- Batch drilling to increase re-use of chemicals;
- Use of Ilenite as weighting agent for WBM;
- Installation of double barriers on all overboard lines;
- Replacement of a large amount of piping and hoses for hydraulic fluids;
- Use of extra barriers to avoid spills;
- Use of a non-toxic Blowout Preventer (BOP) control fluid;
- Cleaning of wells using only mechanical tools – no chemicals; and
- Substitution of chemicals to non-toxic or low bio-accumulation potential.

2.2.2.4 Drill Mud and Drill Cuttings Treatment

Cuttings from the well are extracted from the well bore and returned to the surface with the drill mud. On the platform, the mud is separated from the cuttings for reuse. Cuttings may retain some mud on their surfaces which may result in mud being discharged into the sea on the cuttings.

The following discussion of drill mud and cuttings treatment draws primarily from a recent Environmental Studies Research Funds (ESRF) paper prepared by Stantec. Stantec (2009) evaluated cuttings treatment technology and contains a review of SBM and cuttings compliance. This research document found that the majority of the technology-based limitations pertaining to the disposal of SBM on cuttings worldwide relate to percent retention of mud on cuttings. Discharge guidelines for SBM drill cuttings in Canada (OWTG) are based on best available technology. This guideline evolved from the United States Environmental Protection Agency (USEPA) results obtained from the Gulf of Mexico; however, additional limitations pertaining to the Gulf of Mexico include limitations on discharge distance from shore, toxicity, mercury and cadmium in barite, and the presence of free and diesel oil (Stantec 2009). Appendix C contains a summary of international regulatory requirements and best practices for discharge of drilling muds and cuttings.

The primary function of a typical solids-control treatment system is to efficiently remove the solids from the treatment stream in order to maximize the recovery and recycling of the costly drilling fluids (primary treatment). Maximizing the recycling of drilling fluid (secondary treatment) also reduces the total volume of spent SBM drill fluids that must be disposed upon completion of drilling operations (OGP 2003).

Primary solids control equipment (*e.g.*, shakers, centrifuges) have remained the main components for removal of SBM on cuttings (OGP 2003; CAPP 2001). Although refinements have been made to primary treatment equipment, these technologies remain relatively similar to 2002 designs. There is no one specific treatment process that can be defined for all primary solids-control applications. The system components are selected in number and type based upon the site-specific drilling requirements (*e.g.*, volumes to be treated, variability in geological formation, production rate), and brought online or offline during the course of drilling operations, as required (Stantec 2009).

Secondary treatment systems are additional equipment that may be added to increase drilling fluid recovery and/or assist in achieving stringent regulatory compliance requirements for offshore cuttings discharge. The two most common methods for secondary treatment to reduce drilling fluid retention on cuttings (ROC) are cuttings dryers and thermal desorption. Although other innovative technologies such as microwave heating (a variation of the thermal desorption method) (refer to Shang *et al.* 2005; Robinson *et al.* 2008) and supercritical CO_2 extraction (Saintpere and Morillon-Jeanmaire 2000; Street *et al.* 2007; Esmaeilzadeh *et al.* 2008), are being investigated, further research and development would be needed to implement these methods beyond the laboratory phase.

The design of cuttings dryers is a combination of a fine mesh screen mounted on a rotating basket that generates centrifugal forces for separation. The centrifuge may be horizontally or vertically oriented (Cannon and Martin 2001). The Verti-G™ cuttings dryer from MI-SWACO is an example of a vertical mounted cuttings dryer. The Duster™ from Hutchison-Hayes utilizes a horizontal screen configuration.

In the thermal desorption process, cuttings are heated to the distillation temperature of the base oil, and this temperature is maintained until essentially all of the oil is vaporized. When first developed, thermal desorption required large, fixed onshore facilities due to the space and energy requirements. A thermo-mechanical cuttings cleaner (TCC) system, also known as a hammermill system, has been successfully used both onshore and offshore. The cuttings powder resulting from this process typically has a hydrocarbon content of <0.1% (Stantec 2009).

Land-based technologies, such as biological treatment, also have potential for offshore application. A slurry bioreactor uses the same aerobic biological reactions that occur in land treatment or composting. However, this technology has not been widely used in current offshore operations and its feasibility for offshore application remains uncertain (Thanyamanta *et al.* 2006).

Other alternatives to offshore treatment and disposal include Cuttings Re-Injection (CRI), or transport of the cuttings to shore for onshore treatment and/or disposal (*i.e.*, “skip and ship”, also referred to as “ship-to-shore”). Significant advancements have been made in the last decade with CRI, as demonstrated by the increase in maximum slurry volume injected into a single well increasing from approximately 30,000 bbl to several million barrels (Guo *et al.* 2007). Although CRI requires intricate design and is subject to reservoir constraints, according to Guo *et al.* (2007), CRI technology has grown beyond the development phase and is entering a high growth phase.

Ship-to-shore disposal has been used for disposal of cuttings from wells drilled offshore Nova Scotia. Although this method is being used to meet OWTG requirements, there are safety and logistical issues that must be taken into consideration. In addition, environmental effects such as fuel usage, air emissions, potential for spills in sensitive areas, and onshore treatment, storage and disposal implications must be considered. A key safety concern is the large number of crane lifts needed to transfer cuttings boxes between drilling rigs and onshore facilities. Cuttings handling and transport also poses logistical challenges due to the limited storage space available on offshore drilling rigs. Alternatives for bulk collection, storage and transfer have been developed that avoid the need for cuttings boxes and eliminate safety issues associated with crane lifts (*e.g.*, tanks on rigs can be linked by hose to tank on ship) (Stantec 2009).

Overall, Stantec (2009) concluded that technologies available for the treatment of drill cuttings have remained basically unchanged since 2002, with the exception of advances in cuttings dryers and thermal desorption technologies.

As part of their evaluation of drill cuttings treatment technology, Stantec (2009) evaluated drill cuttings treatment performance, based on information received from two major operators from the Canadian East Coast from 2002 to 2007. The study results indicated that on a whole well basis the 6.9% synthetic oil on cuttings (SOC) was rarely achieved (1 of 15 wells in the Eastern Canada examples studied achieved 6.9% SOC between 2002 and 2007). It was found that the per-well mass average % SOC was 8.46%. Four equipment configurations accounted for discharging the greatest weight of cuttings (see Table 5.3 in Stantec 2009):

- Duster™ Cuttings Dryer, Shaker(s) and Centrifuge x3 (9,658 mt treated and discharged);
- Shaker, Centrifuge x3 (5,343 mt treated and discharged);
- Centrifuge x3 (4,710 mt treated and discharged); and
- Duster™ Cuttings Dryer, Shaker(s) and Centrifuge x3, Duster™ Cuttings Dryer Centrifuge (6,825 mt treated and discharged).

Of these top four, the average percent synthetic on cuttings (% SOC) ranged from 7.09 and 9.55. Stantec (2009) found that during specific periods of treatment, a 6.9 % SOC was achieved; however, the associated treated mass of cuttings discharged (less than 6.9% SOC) represented less than 10% of the total treated mass of 15 wells assessed. Stantec (2009) also reported that according to one operator, drilling operations conducted in the Nova Scotia offshore in 2002 was able to achieve the 6.9%SOC through utilization of a Verti-G™ cuttings dryer, combined with ship-to-shore of some drilling wastes. However, the data provided did not enable assessment of the Verti-G™ cuttings dryer stand-alone performance (Stantec 2009).

The drilling muds that are likely to be considered in Georges Bank petroleum exploration activities will mainly be low toxicity WBM because of the relatively shallow water depth of the bank, with potential use of SBM as dictated by the operational requirements. It is extremely unlikely that OBM would be considered under any circumstance as per the OWTG (2002).

For the Gulf of Mexico, the USEPA worked closely with industry to develop a Best Management Practices (BMP) approach, and this approach essentially requires the operator to devise a program to keep better track of SBM at all stages of handling (Johnston *et al.* 2004). The BMP compliance option includes information collection requirements. Examples include (1) training personnel; (2) analyzing spills that occur; (3) identifying equipment items that might need to be maintained, upgraded, or repaired; (4) identifying procedures for waste minimization; (5) performing monitoring (including the operation of monitoring systems) to establish equivalence with a numeric cuttings retention limitation and to detect leaks, spills, and intentional diversion; and (6) generally to periodically evaluate the effectiveness of the BMP alternatives (Johnston *et al.* 2004).

Johnston *et al.* (2004) showed that implementation of BMPs on Gulf of Mexico drilling programs significantly reduced SBM retention on cuttings and can therefore provide operators with an opportunity to realize benefits for both the environment and their drilling operations. Using data for comparable well intervals from 72 non-BMP wells and 12 BMP wells, retention was reduced from 4.30% (with a standard deviation of 1.18%) to 3.53% (with a standard deviation of 0.96%) (Johnston *et al.* 2004).

2.2.2.5 Modelling and Monitoring Advancements

In the past decade, there have been significant advancements with dispersion and transport modeling to predict the fate and effects of particles and chemicals associated with drilling wastes discharged into the sea. One of these models is the Benthic Boundary Layer Transport (BBLT) model that was developed by DFO scientists at the Bedford Institute of Oceanography. The BBLT was developed to predict the transport and dispersion of suspended particulate drill waste (mainly barite and bentonite) on the continental shelf (DFO 2004). Since 1999, understanding of the model has improved and industry and DFO have used the model for the preparation and review of EAs and Environmental Effects Monitoring (EEM) programs.

Another key advancement in the past decade is the extensive and valuable information that has been gathered from EEM programs. EEM programs have been used to assess the predictions of EAs of offshore oil and gas projects on the Atlantic coast, and are therefore a useful tool for mitigation moving forward.

Stantec (2010) summarizes advancements in scientific knowledge related to modeling and monitoring and discusses areas for further research to refine calculation of potential risks from drilling waste discharges. Upcoming offshore Nova Scotia oil and gas projects such as the Deep Panuke project which is currently under construction, and any future projects will benefit from the combination of knowledge gained from past EEM programs and new technology and practices.

2.2.3 Relevance to Panel Comments

The principal issue in exploration drilling operations relates to the discharge of mud and cuttings into the marine environment which contain SBM or OBM. The regulatory requirements in any given jurisdiction dictate the various drill waste management technologies and practices to be used. Table 2.1 summarizes the treatment options and the advantages and disadvantages, from the operator's perspective, for addressing drilling mud and cuttings discharges.

Table 2.1 Comparison of Technologies for Managing Drill Mud and Cuttings

Method	Advantage	Disadvantage
Onboard primary treatment and discharge to the sea	Low cost. Recovers drill mud for reuse.	Difficult to achieve compliance environmental criteria for contaminants discharge.
Onboard secondary treatment and discharge to the sea	Reduced SOC concentration in discharge. Recovers drill mud for reuse.	Higher cost than primary treatment.
Containment and "Skip and Ship" to shore	No discharges to marine environment.	• Must be treated as a waste product on shore. • Drill mud not recovered for reuse. • Cost of transportation and disposal higher than onboard treatment.
Re-injection into a suitable geological formation	No discharges to the environment.	High cost of drilling and operating a re-injection well.

Operators have demonstrated that they can achieve zero harmful discharge to the sea if required, although this is not without increased costs. Continued monitoring of treatment performance and environmental effects will help address remaining concerns of effects on the marine benthos.

2.3 PRODUCTION (PRODUCED WATER)

Although production scenarios were not the focus of the 1999 Panel Review, a few issues related to the production phase were identified as areas of concern. In addition to fishing exclusion (which has been addressed previously with respect to seismic surveys in Section 2.1), transportation (refer to Section 2.5) and spills (refer to Section 2.6), the key issue of concern associated with production was the discharge of produced water.

Produced water includes formation water, injection water and process water that is extracted along with the oil and gas during petroleum production. Formation water is naturally occurring water which is present within the geological formation. This water can contain high levels of salt, other dissolved minerals and dissolved hydrocarbons present in the formation. Injection water is water (typically sea water) which has been purposely injected into a formation to increase the pressure in the formation in order to enhance the recovery of petroleum hydrocarbons. Process water is a by-product of the various treatment processes used on the platform during exploration or the production process.

Produced water represents the largest volume of any waste product generated in oil and gas production (Clark and Veil 2009) and therefore is of concern with respect to disposal and potential environmental effects. This concern will only increase over time since the amount of produced water increases proportionately with the age of the well (Henderson *et al.* 1999). However, produced water volumes and chemistry are also well or platform specific, depending on deposit characteristics, recovery system specifications, and treatment methods used.

2.3.1 Panel Comments

The potential effects of produced water disposal on Georges Bank ecology were not discussed to any great extent in the 1999 Review Panel Report. The focus at that time was on exploratory drilling which would result in only minor amounts of produced water being generated and discharged into the environment. However, Section 4.2 of the Panel Report (*Cumulative and Remote Impacts)* recognized that produced water would be a major by-product of any commercial drilling program and therefore had the potential to significantly impact marine ecology.

A lab-based study by Cranford *et al.* (1998), which was commissioned by the Review Panel, reported that produced water discharges could be deleterious to the survival of haddock eggs and lobster/scallop larvae at concentrations ranging from 0.9% to 22%. This study was cited as a cause for concern since these are important commercial species for Georges Bank in spite of the fact that these concentrations would only be observed in a lab environment and not in the open ocean. In response, oil and gas industry representatives indicated that produced water discharges could be monitored and treated or re-injected as needed, based on regulatory requirements.

2.3.2 Existing and Emerging Technologies

Since 1999, the OWTG have been revised (NEB *et al.* 2002) to include more stringent guidelines respecting produced water discharge. The overboard oil content of produced water in 1996 permitted a concentration of dispersed oil of 40 mg/L or less, as averaged over a 30-day period, prior to discharge. Average oil concentrations in the discharge stream exceeding 80 mg/L over any 48-hour period were considered to have exceeded normal operating practice and were to be reported within 24 hours to the Chief Conservation Officer.

The 2002 version of the OWTG prescribes that installations will be expected to achieve a 30-day weighted average of oil in discharged produced water of 30 mg/L and that the 24-hour arithmetic average of oil in produced water must not exceed 60 mg/L. An exceedance of either the 30-day or the 24-hour limit must be reported to the Chief Conservation Officer within 24 hours of its occurrence.

The OWTG 2002 version also requires that each operator of a production installation should, as part of its development application, examine and report upon the technical and economic feasibility of alternatives to conventional marine discharge of produced water (*e.g.,* subsurface re-injection, subsea separation, downhole separation), to justify a marine discharge.

The Scotian Shelf developments to date have all used overboard disposal (marine discharge) for produced water. The most recent, SOEP and Deep Panuke projects, have used or are planning to use a produced water polisher in addition to separators and hydrocyclones to help achieve less than the required limits for overboard disposal. The polisher used has an organophillic clay material that traps oils and greases both dispersed and in many cases dissolved. This is an important step forward resulting in very low overboard disposal of hydrocarbons in produced water. The technology can also remove mercury and arsenic. The technology used to date has been “CrudeSorb” as supplied by Cetco Oilfield Services. These types of products are proving to be extremely beneficial in reducing discharges to the marine environment.

In its development application and environmental assessment for Deep Panuke, EnCana Corporation considered four potential alternatives for produced water disposal: treatment and discharge overboard; injection into a dedicated well; simultaneous injection into the condensate/acid gas injection well; and injection into the annular space of an existing well. Each alternative was evaluated in terms of technical suitability, cost, commercial risk, and feasibility. Treatment and disposal overboard was the only option deemed technically and economically feasible and was therefore further evaluated in the context of concept deliverability, safety, and environmental effects. After a thorough review of the alternatives, treatment and disposal overboard was deemed the best technical and commercial option with acceptable environmental risks (EnCana Corporation 2006).

The developments in Newfoundland and Labrador have tended to use subsurface re-injection as the oil reservoirs benefit from the pressure increase of re-injecting the water so it becomes an enhanced oil recovery (EOR) practice and enables increased recovery of the resource.

Produced water technologies focus on removal of contaminants prior to discharge of produced water and/or reduction or elimination of produced water discharge from platforms. Table 2.2 lists a number of new technologies which can be used as part of an overall produced water treatment regime. Actual methods used are site and platform specific and depend on regulatory requirements, economics, and risks associated with produced water discharge (Ekins *et al.* 2005).

Table 2.2 Methods Used to Manage Produced Water Chemistry and Volume (from Ekins *et al*. 2005)

Physical Separation Techniques	Enhanced Separation Techniques	Alternative Techniques	Preventative Techniques
Hydrocyclone	Mare's Tail ®	Non-regenerative absorption	Down hole separation
Skimmer tank and plate interceptor	Centrifuge	Regenerative absorption	Onshore biodegradation
Dissolved gas / induced gas floatation (DGF/IGF)	Compact Floatation Units (CFU)	Membranes	Produced water re-injection (PWRI)
		C-Tour Process System	Onshore biodegradation
		Steam stripping	

Physical Separation Techniques

There are several relatively simple techniques to physically separate oil from produced water. Hydrocyclones are devices which rely on centrifugal force to separate lighter oil from water, whereas skimmers and plate interceptors rely on differences in specific gravity to separate and then "skim off" oil as it floats to the surface. Neither technique is effective at removing dissolved contaminants in water (Ekins *et al.* 2005).

With dissolved or induced gas floatation, gas is injected or pumped into produced water which then strips off oil droplets as it rises to the surface. The foamy surface residue is then removed. Like other physical techniques, DGF/IGF does not remove dissolved contaminants, but BTEX (benzene, toluene, ethylbenzene and xylene) can be at least partially removed if air is used in the process instead of gas (Ekins *et al.* 2005).

Enhanced Separation Techniques

The Mare's Tail ® consists of a fibrous "tail" which attracts and then builds oil droplets into larger droplets which can be more easily removed. This process is applied before hydrocyclone treatment to enhance the effectiveness of this treatment (Ekins *et al.* 2005). A centrifuge uses the same principle applied in the hydrocyclone process, but is more effective at removing smaller oil droplets (Ekins *et al.* 2005).

Compact floatation units (CFUs) act as three-phase water/oil/gas separators which incorporate the use of centrifugal force and gas floatation in the separation process. Unlike other methods described above, CFUs can be used to partially remove dissolved hydrocarbons and alkylphenols along with dispersed oil (Ekins *et al.* 2005).

Alternative Separation Techniques

Alternative treatment techniques being developed include filtration and absorption using non-regenerative materials (*e.g.,* modified clay, wood, fibres) or regenerative media (*e.g.,* macro-porous polymer extraction (MPPE), see for example Meijer 2008). In both cases, produced water is filtered through a medium designed to remove specific contaminates, which can also include the majority of hydrocarbons. However, non-regenerative material needs to be replaced and disposed of onshore once full, whereas regenerative absorption media can be cleaned and reused for several cycles. This technology is not thought to be practical in cases where large volumes of produced water need to be treated, but is considered appropriate for gas facilities (Ekins *et al.* 2005).

Various ceramic and synthetic membranes can also be used to filter hydrocarbons from produced water (Ekins *et al.* 2005). Use of these filters is not without challenges, however, as described in a review by Ashaghi *et al.* (2007). Issues which need to be addressed include the prevention or reduction of membrane fouling during operational use and the development of a cost-effective and non-hazardous method for cleaning fouled membranes.

The C-Tour Process System is yet another enhancement to the hydrocyclone process where a gas condensate is used to increase removal of hydrocarbons. The injected gas condensate extracts dissolved hydrocarbons from the water phase which are then removed in a downstream hydrocyclone treatment (Ekins *et al.* 2005).

Another alternative treatment for produced water is steam stripping; however, this method is only applicable to gas platforms. In this method, steam is used to remove, or strip, hydrocarbons (especially BTEX) from condensed water which results from glycol regeneration on gas platforms. The stripped hydrocarbons are then directed to a condensate treatment system before being discharged (Ekins *et al.* 2005).

Preventative Techniques

Preventative techniques involve reducing or eliminating produced water discharge from platforms. Down hole separation involves using a hydrocyclone device to separate water from oil at the source (*i.e.,* in the bore hole). Separated water is pumped into an underground reservoir and only the remaining concentrated oil/water mix is pumped to the platform for further treatment. With this method, produced water volumes can be reduced by 50% or more and the amount of chemicals needed for processing can be reduced (Ekins *et al.* 2005). There have also been trials using a large separation unit that sits on the seafloor (NETL 2009).

Biodegradation involves using microbes to breakdown hydrocarbons in produced water. However, since this process requires significant time and resources, it is usually only feasible for onshore facilities which would require shipping of produced water for treatment (Ekins *et al.* 2005).

Produced water re-injection (PWRI) is the process of re-injecting produced water into a disposal (dump) well, or into a production reservoir as added pressure support to enhance extraction. In both cases, water must still be treated before re-injection, but it is now removed from the discharge stream. Two types of injection are used, matrix injection where pressure and temperatures are kept constant, and fracture injection where pressures and/or temperatures are periodically changed to cause fractures in receiving well walls to allow for increased injection (Ekins *et al.* 2005).

There are a number of potential complications associated with PWRI (Maersk 2009). These include: increased risk of water ingress (*i.e.,* water moves toward producing wells without pushing hydrocarbons ahead of it); an overall increase in produced water to be treated; increased production of toxic and corrosive hydrogen sulphide (H_2S) since produced water contains nutrients that promote the growth of sulfate reducing bacteria; and increased energy consumption.

Other Technology

In addition to treatment methods described by Ekins *et al.* (2005), there have been other recent developments in produced water treatment and management, some of which may be applicable to offshore conditions. These include:

- The use of sponge gourd (*Luffa cylindrica*) to remove heavy metals through bio-absorption (Oboh *et al.* 2009);
- The use of reverse osmosis technology as a secondary treatment to reduce salt content in produced water (Franks *et al.* 2009);
- The use of pressure-assisted ozonation and sand filtration to remove hydrocarbons from produced water;
- Electrodialysis (ED) and electrodialysis reversal (EDR) technology which uses an electrical field along with ion selective membranes to remove dissolved salts in produced water (Western Research Institute 2008); and
- The use of walnut shell filters to remove hydrocarbons from produced water (BONO Artes).

The Produced Water Management Information System (PWMIS), sponsored by the U.S. Department of Energy through its National Energy Technology Laboratory (NETL) system, provides information on many treatment technologies for both offshore and inshore oil and gas wells (http://www.netl.doe.gov/technologies/PWMIS/).

Produced water treatment technology development and application were discussed at the International Produced Water Conference: Environmental Risks and Advances in Mitigation Technologies (October 17-18, 2007). Proceedings from this conference (Lee and Neff, in press) are expected to be published in 2010.

2.3.3 Relevance to Panel Comments

Preventative and treatment technologies are site and platform specific and depend on regulatory requirements, economics, and risks associated with produced water discharge. Environmental advantages and disadvantages must be considered for each technology, along with technically and economically feasible alternatives. Produced water management must be compatible with management of other waste products, such as drill muds and cuttings and atmospheric emissions. As regulatory requirements for produced water management have become more stringent and understanding of produced water fate and effects in the open ocean environment has improved, technology has also advanced in the past decade.

The general consensus of researchers is that acute effects of produced water on individual development sites in the open ocean are likely to be minor (Lee and Neff 2009), although potential chronic and/or cumulative effects of produced water contaminants on marine ecosystems are still being debated (PRAC 2006). A key area of emerging technology and advancement of science over the next decade will likely be focused on improving measurement and environmental effects monitoring of produced water discharges.

2.4 AIR EMISSIONS

All phases of petroleum exploration, development and production can result in atmospheric emissions. Atmospheric emissions have not been a major regulatory concern from a safety perspective. However, greenhouse gas emissions and climate change have received increasing public and regulatory attention in the past decade.

2.4.1 Panel Comments

Atmospheric emissions received little attention in the 1999 Review Panel Report with the focus primarily being on greenhouse gas emissions and climate change. Acknowledging that greenhouse gas emissions are a complex problem, the Panel noted that natural gas has a lower greenhouse gas intensity than coal, or oil, and that it might serve a useful purpose as a “transitional fuel”. Further comments were in support of overall reduction in energy use, improvement in efficiency, and stimulation of the use of renewable energy sources.

The Panel Report additionally noted comments from presenters on “Natural Gas Use, Flaring, and Environmental Toxicity”. The notes on use refer to comments regarding increases in indoor air pollutants such as “nitrogen dioxide, carbon monoxide, fine particulates, polycyclic aromatic hydrocarbons, and volatile organic compounds including formaldehyde”, further citing potential effects to sensitive parts of the population. The Panel offered no comments on this.

2.4.2 Existing and Emerging Technologies

One of the key updates in the redraft of the 1996 OWTG was the inclusion of requirements for air emissions (NEB *et al.* 2002). Under the current version of the OWTG (NEB *et al.* 2002), each operator of a production installation is expected, as part of its development application, to provide an estimate of the annual quantities of greenhouse gas that will be emitted from its offshore installation as well as a description of its plans to control and reduce these emissions. Operators of drilling and production installations are expected to calculate and report greenhouse gas emissions on an annual basis in accordance with the Canadian Association of Petroleum Producer's (CAPP) Global Climate Change Voluntary Challenge Guide (CAPP 2000b). Also under the OWTG, operators of drilling and production installations are expected to report the type and significance of VOC emissions and report them in accordance with best management practices for oil and gas operations in Canada (*e.g.,* CAPP 1999; CAPP 2000b).

VOC Emissions and Flaring Technology

The best practices for reducing VOC emissions and facility and employee health and safety are closely related. Operators cannot have releases of flammable VOC on the platform for health and safety reasons. This requirement results in the design of the facility being regulated to a number of design codes and other practical design features such as minimizing piping flanges, the use of zero or extremely low leakage valves, routing of safety systems to a flare for combustion (there is an option to cold vent in some select cases), and dehydrator vent gas routed to the flare versus cold venting.

The use of a flare is a key safety feature and reduces VOC emissions in the event of a safety-related trigger (pressure safety valve, emergency shutdown). The flare is an incinerator designed to combust the VOC emissions. The flare is typically elevated to avoid gas dispersion back to the production facility and surrounding equipment for cases where the flare has incomplete combustion or in the event that the combustion system fails. The flare pilot systems (to keep the flare combusting) are typically 100% redundant; however, there are instances where cold venting results due to failure to the ignition system. The height and location of the flare boom in relation to the platform and prevailing winds provides a measure of safety under such conditions.

The Deep Panuke project has facilities to both flare and re-inject acid gas with the latter being the intended mode of operation. Re-injecting the acid gas is both a safety benefit and an environmental benefit. Flaring the acid gas still has a combusted gas that is a safety risk, albeit far less than if it was not combusted. As flares are not 100% reliable to combust, safety is a concern when flaring this gas. Re-injecting the gas mitigates these issues. There is no regulatory requirement for the operator to re-inject this gas.

Flares, if in combustion mode, do need gas compositions that will readily combust. Flares generally have extremely low flow rates routed to them compared to rates during a start-up or safety event. This low rate of flow, coupled with possible composition issues, can make the combustion process inefficient and a small source of smoke. Some flares have steam or air injection to aid in the combustion process while others use the venturi effect to draw in the required combustion air. Some operators choose to add higher energy content gas to make a better combustible gas mixture and use a venturi type flare to increase the flow rate to supply required combustion air.

Carbon Removal and Capture Technology

The control of greenhouse gas emissions is a focus of research around the world. Mitigation measures that avoid the emission of greenhouse gases are being developed, but the technology is still evolving and offshore energy producers are reluctant to use experimental or unproven technology in the offshore environment.

The technological issues surrounding carbon capture are substantive. Because exhaust from combustion systems contains approximately 78% nitrogen by volume, but only approximately 13% carbon dioxide, much of the capacity of air handling systems is used simply to pass through the inert nitrogen fraction. One approach to this issue is to use pure oxygen to sustain combustion, limiting the exhaust volume by a factor of about 5, and reducing the size and energy consumption of the air pollution control systems. Natural gas often contains quantities of carbon dioxide that must be removed to meet commercial sales specification, and this technology is well developed. Another approach is to use chemical stripping agents to absorb and desorb the carbon dioxide from the exhaust. These approaches have different strengths and weaknesses, and are still being evaluated in pilot and full-scale projects. Given that the technology will evolve to a level where the carbon dioxide can be removed and contained in a concentrated exhaust stream, the question of disposal of the gas remains.

Substantial resources have addressed the potential for re-injection of carbon dioxide into the reservoir to enhance yields, and to sequester the greenhouse gas on a permanent basis. In Western Canada, this technique has long been used for enhanced production from reservoirs. A “clean coal” technology research project in Alberta will have carbon capture from the combustion gases, and the carbon dioxide will be sold to a US energy company for injection into a reservoir to enhance recovery. Offshore, the EnCana Deep Panuke project, which is now under construction, comprises a plan for the injection of the carbon dioxide and the sulphur dioxide emissions into a reservoir deep below the seabed. The injection concept, such as that selected by EnCana, remains the most promising current technology for storage of the carbon dioxide.

IEAGHG, the greenhouse gas section of the International Energy Agency (www.ieaghg.org) is one of several international consortiums sponsoring research into the area of greenhouse gas sequestration in wells and reservoirs. The first meeting of the Oxyfuel Combustion Conference occurred in September 2009, and other conferences, such as the Electrical Utilities Environment

Conference (www.euec.com) has had sessions focusing on carbon dioxide removal and clean combustion since 2007.

In 2009, the Carbon Capture Storage Research Consortium of Nova Scotia (CCS Nova Scotia) was formed. CCS Nova Scotia is a not-for-profit corporation whose members include the Province of Nova Scotia, Nova Scotia Power Inc. and Dalhousie University. CCS conducts multidisciplinary research into the issues involved in the capture, transport, storage and monitoring of stationary sourced carbon dioxide emissions.

In summary, advances in technology pertain mainly to the management of GHG, with the focus on carbon capture technology (*e.g.,* capturing carbon, and of disposing it in sedimentary rock reservoirs). As issues of climate change continue to rise in importance, further technological advancement in this area is expected.

2.4.3 Relevance to Panel Comments

Environmental effects of greenhouse gas emissions, climate change, and ocean acidification are addressed in the *Preliminary Review of Environmental and Socio-economic Issues on Georges Bank* (Stantec 2010). While effects of climate change and ocean acidification are global in nature and not specific to Georges Bank, these are issues that must be considered in any new developments that could occur should the moratorium be lifted.

A lack of alternative commercially available fuels and power systems will result in fossil fuels continuing to provide the major portion of energy for power systems on production platforms. The injection of waste gases from production is a viable alternative to flaring in offshore production platforms under normal operation conditions, although not without environmental issues itself. The use of flaring as an emergency disposal of waste gases is not likely to change in the foreseeable future.

2.5 PETROLEUM TRANSPORTATION (PIPELINES AND TANKERS)

As an oil or gas discovery moves into the development phase, decisions are made regarding transportation of the product to market. Export options include transportation by tanker, as was done in the COPAN project, or subsea pipeline as is being done by the SOEP and Deep Panuke projects on the Scotian Shelf. Each option has several alternatives in design and implementation with various advantages and disadvantages. The following discussion considers transportation issues and emerging technologies which influence potential environmental effects associated with transportation.

2.5.1 Panel Comments

During the public hearings, presenters frequently expressed concern about cumulative effects related to transporting oil or gas by pipeline or tanker. In addition to concerns related to potential spills, presenters expressed concern about pipelines related to interference with fishing activity and barrier to lobster migration.

2.5.2 Existing and Emerging Technologies

Pipelines and tankers remain the most common and cost effective methods of delivering petroleum products from the wellhead to shore as the Nova Scotia experience has demonstrated. The approach used depends on the nature of the product in the reservoir. Subsea oil pipelines have been used successfully around the world to carry crude and processed petroleum products. The Sable Gas pipeline is an example of a pipeline carrying crude or unprocessed natural gas product. The Deep Panuke pipeline will carry processed or market gas to shore. The COPAN project employed a very large crude carrier (VLCC) moored to a catenary anchor leg mooring (CALM) buoy near the production centre to transport light crude products from production (Figure 2.4). Both pipeline and tanker options are discussed below from a technological perspective.

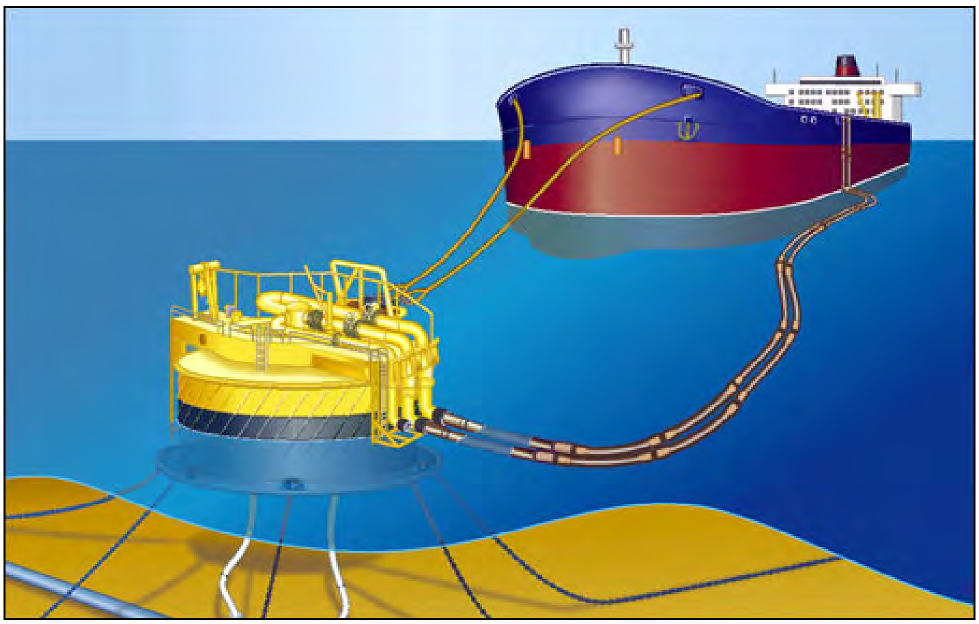


Figure 2.4 Diagram of CALM Buoy and Tanker Filling System (courtesy of IPS Services)

Tankers

Large devastating tanker spills have prompted emerging technologies to focus on tanker safety and spill prevention. Table 4.3 in *the Preliminary Review of Environmental and Socio-economic Issues on Georges Bank Report* shows worldwide annual tanker spill statistics for the period

1990 to 2008. In the period from 1990 to 1998, 1,109,000 tonnes were lost from tanker spills. In the following period, 1999 to 2008, total losses were 243,000 tonnes (ITOPF 2008)). The data are indicative of a trend in the reduction of tanker related oil spills.

The *Canada Shipping Act, 2001* and MARPOL are key elements which regulate shipping in Canadian waters. The *Canada Shipping Act, 2001* is the principal legislation governing safety in marine transportation and protection of the marine environment. The main difference between the Act previous to the updated *Canada Shipping Act, 2001* enacted in 2007 is a less prescriptive and more performance-based approach.

MARPOL is an international convention whose aim is the prevention of pollution of the marine environment by ships from operational or accidental events. Important technological advances to protect the marine environment from spills have occurred in shipping including the phase out of single-hulled tankers. International requirements for double-hulled oil tankers were introduced in 1993 through an amendment to Annex I of MARPOL. Amendments to MARPOL were adopted in 2001 and became effective in 2002. These amendments accelerate the phase-out schedule for large single-hulled tankers beginning in 2003 with final phase out occurring in 2015. There are, however, some provisions for allowing existing tankers to continue to operate (*i.e.,* existing tankers that meet the side protection requirements in the International Bulk Chemical Code for type 2 cargo tank locations and the bottom protection specified in the regulation 13E(4)(b) of Annex I of MARPOL).

2.5.2.1 Pipelines

The installation of production facilities, seabed installations and pipelines have significant financial risks, are constrained by the physical environmental conditions of the site and face important issues associated with environmental effects.

In 2008, the NEB and the CNSOPB signed a memorandum of understanding to increase the efficiency and effectiveness of offshore pipeline regulation. As construction, operation, decommissioning, abandonment and removal of offshore pipelines is within the jurisdiction of both agencies, the new agreement reduces regulatory overlap by setting criteria for areas where cooperation can occur, such as data sharing, emergency management, monitoring and enforcement.

Key environmental and socio-economic issues associated with pipelines include pipeline failure (*i.e.*, spills), interference with fishing activities and effects on mobile benthic organisms (*e.g.*, lobster). As noted in Stantec (2010), laboratory studies and EEM results have shown that environmental effects of pipeline installation on the marine benthos and lobster migration to be temporary and minor. Technologies associated with pipeline installation are discussed below.

Spill risks associated with subsea pipelines are generally related to physical damage or materials or weld failure. Pipelines may also be affected by the type of product being carried and the formation of waxes and residues inside the pipeline which impede its function. Adherence to construction standards and maintenance reduce potential risks associated with pipelines operations. Section 2.6 provides more information on accidental events.

Marine pipeline infrastructure can be a concern for commercial fishing license holders due to the possibility of causing damage to gear. Operators also consider the effect of fishing gear on subsea pipelines. In 2006, Det Norske Veritas (DNV) issued DNV-RP-F111 as an update to DNV Guidelines No.13, "Interference between trawl gear and pipelines", which was issued in 1997. This Recommended Practice provides criteria and guidance on design methods for pipelines subjected to interference from trawling gear (DNV 2007). Although pipelines are designed to withstand trawling activities, the presence of subsea inter-field pipelines in a production field may require exclusion of fishing activities using bottom gear. Product pipelines can be buried through areas where there is extensive fishing and are typically buried where water depths are less than 80 m.

Route Selection

Route selection is one of the key aspects which can serve to minimize effects of pipeline installation. Developments in seabed mapping over the past decade could have important implications for pipeline planning and design, thereby minimizing environmental and socio-economic effects of this activity.

The planning and design of complex subsea structures has been aided over the past decade by enhanced seabed mapping technology and, in particular, multibeam bathymetric mapping.

The application of multibeam bathymetric technology has resulted from the merging of three technologies: large powerful computers, precision navigation systems using GPS (global positioning system) and the development of multibeam sonar hardware to emit the precision multiple sound signals that cover large swaths of seabed. Accurate ship motion sensors are also required to remove unwanted artifacts from the data.

What results from the integration of these technologies are sometimes termed “sound images of the seabed” (Wille 2005). The images resemble aerial photographs of the land surface and the maps appear as if the water was drained and one is flying over the seabed with the sun setting at a low angle (Figure 2.5). Aerial photography technology has been around for over 70 years and has revolutionized understanding of the earth’s land surface: its geology, biology, and topography.

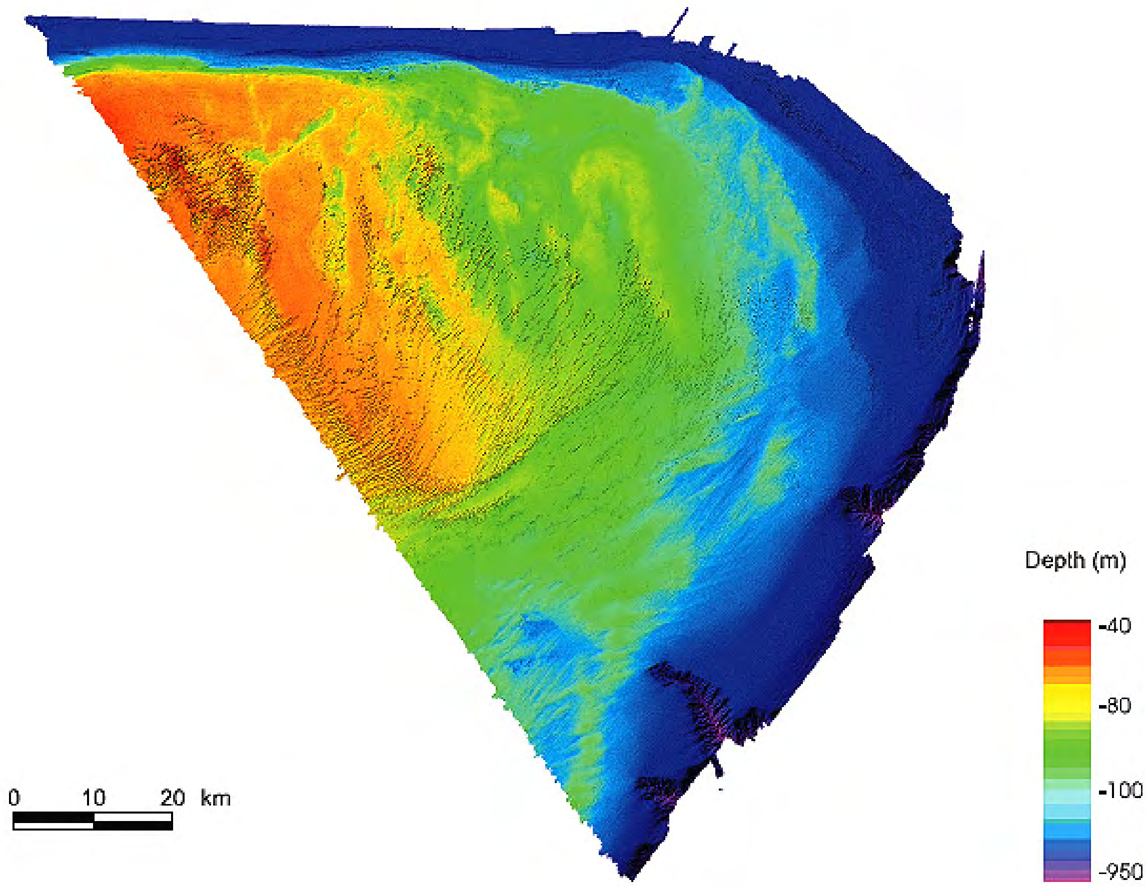


Figure 2.5 Coloured Shaded Relief Map of Bathymetry for Eastern Georges Bank Based on Multibeam Bathymetry (Kostylev *et al.* 2005)

In addition to mapping the shape of the seabed, multibeam bathymetry can produce quantitative maps of seabed slope and hardness that indicate the character of the material of which the seabed is composed. This facilitates the collection of only a few well-positioned samples to characterize the sediments, in contrast to older sample-intensive methods of sample grid surveys with hundreds of stations based on a mathematical grid.

With the collection of multibeam bathymetry, 100% of the seabed can be insonified and this allows for the confident assessment of feature orientations such as sand bedforms, trawl marks, moraines, *etc.* Multibeam bathymetric mapping is now considered a mature technology with calibration and georeferencing a main component. Resolutions have increased such that in a shallow water of 50 m, 20 cm or better is achievable. This makes these systems comparable to bottom photography and, at the very least, the essential ground truth for bottom photography.

Positioning with these systems is also very accurate as they are hull-mounted and referenced to shipboard GPS antennae.

The only maps of sediment distribution and seabed features in the Georges Bank region were by Fader *et al.* (1988), Valentine *et al.* (1992) and Poppe *et al.* (1989). These assessments were largely based on seabed sample grain size analysis while Fader *et al.* (1988) utilized the interpretation of sidescan sonograms to understand seabed morphology and bedform attributes. These assessments were regional in approach and lacked detail both on morphology and sediment type.

In the last two decades, seabed surveys and, in particular, multibeam bathymetric mapping have provided important insights to and understanding of the ecological features of Georges Bank and surrounding areas. The interpretation of multibeam bathymetry (Todd and Shaw 2009) has provided the basis for an understanding of the glacial and post-glacial history of the seabed by characterizing features such as moraines, eskers, drumlins, drainage patterns, ice scour troughs, *etc.* It has clarified the sea level history by revealing former sea level positions, former deltas, transgressed regions and attributes of these previous positions. The images of sediment bedforms such as sand waves, dunes, barchans, and megaripples have provided an unprecedented understanding of seabed stability and sediment transport (dynamics). Bedform symmetry and serial surveys are now clearly able to show directions and rate of sediment transport. The interpretation of scoured regions and areas of sediment buildup provide insight into both short- and long-term erosional and depositional processes. Newer higher resolution multibeam bathymetric systems can also portray bioherms and communities of organisms on the seabed that can be differentiated from sediments and bedrock.

Multibeam bathymetry has been collected across Georges Bank and in Georges Basin and Northeast Channel from a variety of different surveys. The data for the Georges Bank portion was collected in a cooperative program largely funded by Clearwater Fine Foods Incorporated who also supplied the survey vessel, with the Canadian Hydrographic Service and the Geological Survey of Canada. The information collected from Georges Bank is to remain confidential to Clearwater until January 1, 2013, but the data are permitted to be used for scientific purposes to further the bathymetric, sediment and habitat programs of the Geological Survey of Canada and Fisheries and Oceans Canada at the Bedford Institute of Oceanography.

Pipeline Installation

The pipeline installation process can begin once the appropriate route has been determined and the design requirements (*i.e.,* size and materials specifications, etc) completed. Various methods may be used to install pipelines. In deeper water, the pipe lay vessel may use a dynamic positioning system, consisting of a surface navigation system and subsea acoustic positioning system integrated with the vessel's propulsion and thrusters to maintain course and speed over the route. In shallow water, the pipe lay vessel may employ a system of anchors and winches to move the barge along the route. Anchor handling support vessels continuously lift and deploy the anchors as the lay barge travels along the route. The anchors and anchor cables are in contact with a large area of the seabed on either side of the pipeline route. Seabed biota and features can be disturbed during this process.

In coastal areas of Atlantic Canada, fishing activities on the seabed may take place in water depths up to approximately 80 m. EnCana's Deep Panuke pipeline is buried in water depths up to approximately 85 m to avoid contact or interference with fishing (EnCana 2006). Burial of the pipeline requires that a trench is plowed into the seabed into which the pipeline is placed. The trench can then be infilled, as is the case with Deep Panuke, or left to infill through natural processes. In deeper water, trenching is used to ensure that the pipeline is in continuous contact with the seabed and that there are no areas where the pipeline is suspended free of the seabed (spanning).

Jetting using high pressure water may also be used to excavate pipeline trenches. A system of high pressure water jets can remove sediment from beneath the pipeline. The use of this method is subject to the type of sediment along the route. Developments are taking place to enhance trenching systems using water jets for sandy areas and cutting systems for hard areas of the seabed (Stewart *et al*. 2010)

Under some circumstances, such as avoidance of sensitive benthic habitat or physical obstruction, horizontal directional drilling (HDD) may be used rather than trenching (CAPP 2004). This technology may be applied to the area of the shore approach of the pipeline. This technique requires an onshore drilling platform capable of drilling a horizontal hole greater than the diameter of the pipeline through the shallow geological formation of the nearshore and seabed. This hole then exits the seabed at a selected location away from the obstruction area. The pipeline is then pulled through the hole to be connected to the offshore section at one end and the onshore section at the other.

2.5.3 Relevance to Panel Comments

Regulatory updates and improvements in tanker construction have reduced risk of spills related to transportation of oil and gas products. Advances in seabed mapping are being used by the fishing industry to focus fishing efforts and may also result in more precise routing of pipelines to minimize environmental (*e.g.*, benthic disturbance to sensitive habitats) and socio-economic (interference with key fishing areas) effects during the planning phase of pipeline routing. These advances also help identify engineering constraints (*e.g*., potential geological failures), thereby minimizing risks of pipeline failure. Each pipeline installation method has its own advantages and disadvantages and none is without environmental effect. The nature and magnitude of effects is project-specific depending on the technology used and the receiving environment. Based on EEM results from the SOEP pipeline installation, evidence has shown that effects are short-lived, with recovery of the habitat occurring shortly after pipeline installation (one to three years) (SEEMAG 2001).

2.6 ACCIDENTAL EVENTS

Spills may result during exploration or production operations from equipment failure, human error or accidental events such a vessel collision. Typically spills result in the release of a finite quantity of chemical or petroleum product. Blowouts are uncontrolled releases of over-pressure gases and fluids from a reservoir and are difficult to control. Many of the components of drilling and production equipment are purpose-built for well control and safety. The complexity, scale and environmental conditions under which exploration and production take place exacerbate the risks of accidents occurring. Vessels working alongside drilling platforms, the transfer of cargos by crane, and transfers of fuel from the supply vessel to the platform offer opportunities for accidents to occur. Hydraulic systems, mud pumps, well fluids, and process fluids are transferred by pumps and hoses which may be vulnerable to accidental events particularly under extreme weather conditions. The industry and regulators have undertaken to improve safety and prevent spills from occurring. Blowouts are a rare occurrence due to improved well design and control, as well as improved training of personnel.

The industry and regulators have taken steps to improve the record of the industry related to accidental events and spills. Existing and emerging technologies as well as updated mitigative procedures have resulted in improved accident prevention and emergency response.

2.6.1 Panel Comments

Concern regarding potential effects of spills and blowouts on the Georges Bank ecosystem and fisheries was arguably the most significant issue the 1999 Review Panel had to consider in their review. Although it was recognized that the probability of a large blowout would be low, presenters including DFO and Environment Canada stressed that even small spills could trigger international concerns and result in population effects on marine species. Consultants for the petroleum industry, on the other hand, argued that the most serious risk from spills was to seabirds, with negligible risks to marine mammals, pelagic fish, demersal fish, shellfish, phytoplankton and zooplankton.

A related topic of discussion during the 1999 review was “safety and assistance at sea”. Benefits of having rigs present in the offshore, personnel training, detailed planning, availability of helipads and fuel for search and rescue operations, and greater ability to deal with medical emergencies occurring on vessels in the area were acknowledged.

2.6.2 Existing and Emerging Technologies

Potential blowouts refer to the loss of control of a well which results in a release of petroleum hydrocarbons into the sea and/or atmosphere. Such events are rare, however, their occurrence cannot be ruled out. Hurley and Ellis (2004) reported the probability of a blowout occurring during exploration as 1 in 1,800 years (assuming two wells drilled per year) with shallow blowouts occurring more frequently than deep well blowouts.

These events can have severe environmental effects and can result in significant economic costs to the industry and other marine resource users. In the past decade, the industry has continued to make improvements in well control technology and advanced scientific understanding of reservoir geology and geophysics. A review of industry performance demonstrates a declining trend of spill events. The average annual oil spillage from petroleum industries (including exploration, transportation, development, and production) has decreased 46% from 1997 to 2007 and 77% from 1969 to 2007 (API 2009).

Recent spill and blowout events in other parts of the world, including the 2009 Montara blowout in the Timor Sea, and the 2010 Deepwater Horizon deepwater blowout in the Gulf of Mexico, although tragic, do not negate the fact that the overall trend of spills and blowouts is decreasing worldwide. Investigations into these events will most likely result in lessons learned in terms of improved technology and procedures. However, in spite of potential further improvements and advancements, there still remains an element of risk.

The industry has established improved technical training for offshore operations personnel and has mandatory safety training requirements for all personnel working offshore. Offshore exploration drilling requires helicopter support, supply and safety vessel support and the round-the-clock drilling operations sometimes under extreme weather conditions. Such operations cannot be made risk-free and accidental events where contaminants are released cannot be ruled out. The pressures experienced in some wells are extremely high and the substances in the formations can be extremely flammable and toxic. Therefore, there are risks in exploration drilling that must be managed continuously. Regulations are in place which established procedures and equipment specifications for exploration drilling. In the past decade, the industry has established minimum standards for training and experience for offshore personnel responsible for drilling operations. Because of the inherent risks, the possibility of blowouts and associated spills, although low, cannot be ruled out.

Spills from offshore platforms can occur during any phase of a project; however in the unlikely event that an oil spill was likely to occur, there is a greater chance of the spill occurring in the production phase. However, statistics from the CNSOPB and C-NLOPB also indicate a declining trend of platform spill events.

The following sections describe progress that has been made in accident prevention and response.

2.6.2.1 Accident Prevention

Accident prevention is a main element in all phases of offshore work. The consequences for personal safety, environmental effects and cost are significant and are major issues in terms of liability for operators.

As discussed previously, a blowout is caused when well control systems fail and formation pore pressure is greater than the wellbore pressure at depth. A "kick" occurs when formation fluids begin to flow into the wellbore and up the annulus and/or inside the drill pipe. If the well is not shut in, a kick can quickly escalate into a blowout. Modern well control techniques and technology use the concept of multiple barriers to minimize risks associated with blowout events. These preventative and response barriers may include prediction techniques (*e.g.*, drilling hazard assessments, pore pressure prediction); drilling practices for early detection and prevention of kicks (*e.g.*, mud logs, logging-while-drilling and pressure-while-drilling instrument readings); well design to prevent kicks (casing design, BOP system), advanced response to contained kicks (*e.g.*, containment), and finally, well kill. Specific advances in blowout prevention equipment include enhanced BOP stacks with built-in redundancy (*e.g.*, increased number of pipe rams (closing/sealing component on a BOP) and/or adding a duplicate BOP stack on a drillship (Imperial Oil 2010)).

The management of risk and reduction of accidents has been the primary motivation behind the development of regulations and guidelines and the industry's establishment of mandatory training for offshore personnel. Significant improvements have taken place in offshore safety training and the ability for emergency response and rescue.

In 2008, the Canadian Association of Petroleum Producers (CAPP) established the *Atlantic Canada Offshore Petroleum Industry, Standard Practice for the Training and Qualification of Personnel* (Training Standards) which provides descriptions of the minimum training standards and qualifications which apply to various positions and levels of responsibility for offshore personnel (CAPP 2008). This document has been reviewed by a committee composed of members and regulators including the CNSOPB. These Training Standards are now cited as the reference for qualification for offshore workers. Training and qualification are an essential aspect of offshore safety and CAPP refers to the findings of the investigation into loss of the Ocean Ranger where these factors played a role (CAPP 2008). Safety practices and training fulfill the dual functions of reducing the risk of accidents occurring and reducing effects of accidents on personnel and the environment.

Another key element in accident prevention is the use of a safety (exclusion) zone. Safety zones are used to control the proximity or approach of unauthorized vessels to an offshore platform or drilling rig. Around offshore platforms, the safety zone prevents collisions which may have serious consequences for the vessel operators and operations personnel. In an extreme case, a collision could result in loss of control of the well and loss of life. The exclusion or safety zone around a jackup rig operating on the Scotia Shelf is typically a 500 m radius. Other than supply vessels, work boats and safety standby vessels, no other vessels are allowed within this zone. An anchored semi-submersible will have a safety zone around the perimeter of the anchor pattern. Standby vessels can be called upon to intercede with commercial fishing vessels which transgress into the safety zone around drilling or production operations.

Seismic vessels have an impaired ability to maneuver while equipment is being towed and therefore collision avoidance capability is greatly reduced. A 500 m safe navigation area centered on the towed airgun array is provided to reduce potential vessel accidents. Improved navigation systems and the availability of GPS and radar for fishing vessels reduces potential navigation errors and improves hazard identification during conditions of poor visibility. Tail buoys on towed arrays are equipped with radar reflectors as warning devices.

2.6.2.2 Emergency Response and Countermeasures

The level of response required to address spills and blowouts depends on the size and nature of the spill event. Most spills are addressed by the operator using onboard facilities or the facilities available on standby support vessels. All spills in excess of allowable limits are reported and regulators lead the investigations. The regulator may declare an environmental emergency where a spill is of "sufficient quantity to cause or be capable of causing serious damage to the environment or to endanger human health because of its presence in the environment" (CNSOPB 2007).

In 1999, CNSOPB and Environment Canada (EC) renewed their Memorandum of Understanding (MOU) regarding their roles in regulating the offshore petroleum industry which includes their roles in emergency response. "Annex A: Contingency Plan for Spills" was added in June 2007 to revise the original document. This document included provisions for the roll of the Regional Environmental Emergencies Team (REET) to be chaired by EC in addressing offshore emergency spills. EC provides scientific advice to CNSOPB and has authority under the *CEPA* and the *Fisheries Act* with regard to environmental protection and enforcement. The Coast Guard has jurisdiction over the cleanup of spills from vessels and platforms during transit. All spills in excess of allowable limits are reported to the Canadian Coast Guard Operations Centre (CCGOC) who provide the reports to the responsible agencies. The CNSOPB is responsible for providing information to the other agencies and for investigating the spill event.

The operators have resources to address spills. These resources include spill containment systems on board the supply vessels and platforms and personnel who are trained in the use of this equipment. In addition, the East Coast Response Corporation (ECRC) is a private company with large-scale emergency response capacity to address major events. Operators have memberships in this corporation and can call on these facilities in emergency situations. ECRC has an emergency management system with trained personnel and an inventory of spill containment and oil recovery equipment which can be mobilized to meet offshore emergency spills.

Oil spill response requires equipment suited to the environment in which the release occurs. In Atlantic Canada, open ocean conditions require large scale systems suited to the environment of the Atlantic Ocean. The primary types of technologies which have been developed to respond to a major oil spill in the open ocean include:

- Oil spill booms to contain the spread of released oil;
- Skimmers and absorbents to collect released oil; and
- The application of chemical dispersants to break up the oil molecules on the sea surface and allow their distribution into the water column.

Oil spill booms have a flexible floatation chamber and a weighted curtain which act as a fence to control the spread of the spill. Oil spill booms are deployed by vessels in the initial stages of an emergency response to surround and contain floating petroleum products.

Skimmers and absorbents can be deployed within the boom to recover the spilled product. Skimmers for offshore spills use mechanical means such as suction, brushes or plate discs to physically remove and collect the oil product so that it can be pumped to a recovery vessel.

Absorbents are typically a floating oleophilic cloth-like material which soaks up oil product into the fibers. The absorbent materials can be deployed as a boom, sheet, pads or particles which can be recovered after contacting the spill. Absorbents may also be used on skimmers as another means to separate oil from water.

When applied to a spill, dispersants chemically break up oil molecules and allow them to sink into the water column where natural bio-degradation processes can take place. The harsh environment of the North Atlantic can limit the ability of operators to deploy oil spill response equipment from vessels under all weather conditions (DFO 2009). Dispersants can be deployed from aircraft or vessels more quickly and under more severe weather conditions than spill containment gear (Trudel 2004).

Annex A of the Memorandum of Understanding (MOU) between the CNSOPB and EC provides for co-operation between these two agencies in responding to offshore spills. Provision for the approval of the use of “spill treating agents” (dispersants) is included in this document. Only products which meet effectiveness and toxicity standards approved by EC may be used.

The use of oil dispersants as a tool for spill response has been the subject of discussion by industry and regulators. The basis for the application of dispersants lies with benefits of preventing effects on seabirds and mammals, avoiding the effects of oil on coastal areas and estuaries and preventing fouling of fishing gear. The difficulties associated with their use relate to the effects of dispersed oil on fish and benthic organisms and the issues related to tainting of commercial species. Dispersants must be selected for the type of oil product in the spill. Therefore no one dispersant is suited to all spill conditions (Trudel 2004).

Oil spill response is the subject of ongoing research programs which include the following examples:

- Development to enhance the recovery capability of skimmers (MMS 2009c);
- Studies on the application methods, effectiveness and toxicity of dispersants (DFO 2009, MMS 2009c);

- Development of Chemical “herders” to physically concentrate spills to enhance physical recovery methods (MMS 2009c); and
- *In situ* burning and improved methods for collecting residues from the burned oil spill (MMS 2009c).

Research programs are being conducted by the Centre for Offshore Oil, Gas and Energy Research (COOGER) in Canada and the MMS Technology Assessment & Research (TA&R) Program, Oil Spill Response Research Program (OSRR) in the U.S. Many of the MMS programs are joint industry and international projects which provide for the exchange of research data and technological information.

2.6.3 Relevance to Panel Comments

Continuous improvements in standard operating procedures, training, and equipment have resulted in reduced risk of accidental events. In spite of these advances, there will always remain a degree of environmental risk associated with offshore petroleum activities. With respect to Georges Bank, the major concern would be a spill event that would coincide in time and place with a spawning event. It is predicted that a spill occurring on George Bank would initially form a slick which would be subject to evaporation (removing 40-50% of oil in the first 24 hours) with the remaining oil disappearing after one to two weeks due to high rates of vertical mixing on Georges Bank (Boudreau *et al.* 1998). Environmental effects and spill response would depend on various factors, including specific location, timing and nature of spill material. Enhanced training, ongoing spill response research, and improved coordination amongst regulatory bodies, petroleum operators, and other ocean users (*e.g.*, commercial fishing interests), will serve to reduce risk of accidental events on Georges Bank.

3.0 Summary of Residual Issues and Research Recommendations

An important part of revisiting the 1999 Panel Report decision factors in light of current information is determining the residual issues which may remain in spite of technological advances made in the last ten years. New information focuses on those technological updates which may allow risks to be effectively mitigated and identify those which currently have residual uncertainties.

Information presented in this report, including the professional opinion of study team authors on residual issues and research recommendations, has been provided to help inform upcoming decisions regarding the status of the Georges Bank moratorium. Any determination of the significance of potential environmental effects associated with these issues would presumably be the subject of a future environmental assessment of oil and gas activities on Georges Bank which is outside the scope of this evaluation.

In the period since 1999, the offshore industry in Nova Scotia has seen continuous development of technologies to improve operations, improve safety and reduce environmental effects and discharges to the marine environment. Regulations and guidelines have also evolved with the experience gained in the offshore operations on the Scotian Shelf, offshore Newfoundland and Labrador and in other jurisdictions. The focus of regulations and guidelines has been to improve safety for offshore personnel and to protect the marine environment. Despite growth and maturity of the industry, technologies are still evolving. In some cases, concerns raised in the 1999 Review have not been fully addressed by updated technologies, yet advances in scientific knowledge and mitigation have served to minimize potential risks.

Seismic surveys are normally the first major field activity to be conducted in areas of potential development. Although there are developments for alternative energy sources to replace seismic airguns, it is evident that these alternatives are not sufficiently developed for commercial application and/or they may only be used to supplement conventional seismic surveys. Therefore, in the short-term, airguns remain the industry standard and concerns regarding the potential effects on marine species respresent a residual issue. The Statement of Canadian Practice with Respect to Mitigation of Seismic Sound in the Marine Environment (DFO 2007) is an example of an evolving mitigation that is reviewed and updated regularly to provide the industry with measures to reduce effects from seismic surveys.

Residual issues concerning drilling often focus on the discharge of mud and drill cuttings and their potential effects on the marine environment. These discharges accumulate on the seafloor and therefore commercial ground and trawl fisheries are concerned with uncertainties related to the effects on species which they harvest (*e.g.*, tainting, smothering, and sublethal effects). Although technology is evolving to improve treatment and disposal of drill waste, upgrades to dispersion and risk assessment models and an improved understanding of environmental effects gained primarily through environmental effects, monitoring have addressed many of the risks identified by the 1999 Review Panel.

Hydrocarbon production projects can produce long-term discharges such as produced water or waste gases. Regulations and industry guidelines are continuously evolving to incorporate the use of new technologies and promote the concept of “best available technologies”. One such technological innovation is the injection of produced water and/or waste gases into geological formations.

Concern regarding potential effects of spills and blowouts on the Georges Bank ecosystem and fisheries was arguably the most substantial issue with which the 1999 Review Panel had to contend. Advances in technology, training, and procedures have resulted in a decreasing trend in spills worldwide.

A summary of the issues raised in the Panel Report with respect to technological advances in seismic exploration, exploration drilling and petroleum production technologies is provided in Table 3.1. Residual issues which remain in spite of (or in some cases originate from) these technological updates are also presented. The majority of these residual issues are not unique to Georges Bank, rather they are issues facing offshore petroleum projects globally. Research recommendations are included which could serve to further advance new technologies and practices in offshore petroleum developments. The majority of these recommendations are not specific to Georges Bank, but are presented here to help provide context to the current state of knowledge on those issues.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Seismic Surveys	• Opposing perspectives on risk of seismic surveys and level of information required to determine risk. • Key issues included potential physical effects of seismic energy on fish and fish larvae; potential effects on fish behavior; potential effects on marine mammals; and effects on access and crowding. • Seismic exploration vessels will disrupt fishing patterns and can negatively affect catchability of groundfish. • The presence of a safe navigation area would disrupt fishing activities and potentially lead to overcrowding in other areas.	• Innovations in alternative sound sources such as vibroseis are taking place but are not sufficiently developed for industrial application. • Airguns will likely remain the standard energy source for the seismic industry in near future (~5-10 years). • Seabed logging (SBL) surveys are an emerging technology which relies on airguns as the sound source. • Electromagnetic (EM) technology complements acoustic type surveys; however, this technology is still developing. • 3D seismic programs have become common practice in the industry to improve drilling success. • Large streamer arrays used in 3D seismic programs may impede the maneuverability of the seismic vessel and result in exclusion of other vessel activities in the area.	• There are potential sublethal effects on individual fish in the immediate vicinity of the seismic airgun array. • Alternatives to air guns have not been subject to as rigourous environmental review and therefore their effects are less understood. • The use of coil surveys and SBL surveys may provide a method to alleviate some of the access and crowding issues; however, there will need to be cooperation between resource users.	• Conduct detailed health evaluations of key individual fish and benthic invertebrate species exposed to seismic-level noise pressures (Hurley 2009). • Conduct pilot study and EEM for use of alternative energy sources to airguns. • Conduct research and stakeholder consultation comparing access issues between traditional seismic survey and coil surveys.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Drilling (Muds and Cuttings)	• Two basic types of drilling muds: water-based (WBM) and oil-based (OBM). Synthetic-based mud (SBM) is new and not widely used due to cost. • Laboratory experiments suggest sublethal effects of bentonite and barite on scallops could be experienced up to 40 km from discharge point. • Dispersion of drilling mud is not fully understood. • Probability of significant harmful effects from disposal of drilling discharges near Georges Bank cannot be discounted.	• WBM and SBM are used for offshore drilling in Atlantic Canada; OBM is not used. • The revised Offshore Waste Treatment Guidelines (OWTG) (NEB *et al.* 2002) require concentration of 6.9 g/100 g or less oil on wet solids. • There are limited new technologies available which may be applied to the treatment of cuttings. • Development of risk assessment models, coupling transport models with biological effects models, provides greater understanding of fate and effect of drilling discharges. • In some locations, mud and cuttings have been re-injected into the geological formation for disposal during multi-well development drilling. • Directional drilling can provide exploration into geological formations located beneath areas of sensitive or important marine habitat.	• Zero harmful discharge practices are not widely understood and are costly. • Alternative treatment methods require additional testing before they are likely to be considered commercially viable.	• Investigate applicability and cost of zero harmful discharge practices in Atlantic Canada.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Production (Produced Water)	• Naturally occurring contaminants present in formation and produced water in high concentrations can be toxic to marine species including important commercial species on Georges Bank.	• Continuous revision of the regulations and industry guidelines has taken place since 1999 which incorporate the use of new technologies in production operations and promote the concept of "best available technology". • Re-injection into the geological formation has developed as a method for disposing of produced water and waste gases which require disposal. • Fate and transport models have been developed which improve understanding and predictability of produced water movement and related effects. Focus now is on identification of contaminants of concern in discharges. • Treatment technologies have been developed which reduce harmful discharges in produced water. One such technology has been successfully applied in the SOEP project.	• Re-injection wells for waste disposal (*e.g.*, produced water) are expensive to install and operate. Alternative disposal methods are required during maintenance and downtime. • Dilution is usually very rapid, making it very challenging to monitor toxicity after release to ocean.	• Explore solutions for reducing costs associated with installing and operating disposal wells and technical solution to avoiding the need of alternative disposal during maintenance and downtime. • Continue development of chronic toxicity studies to support development of cost-effective and sensitive monitoring protocols for regulatory use in EEM programs. • Continue research on identifying contaminants of concern in produced water streams.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Air Emissions	• Natural gas can be seen as a useful transition fuel away from coal and oil although it still results in greenhouse gas emissions.	• Updated OWTG (NEB *et al.* 2002) include reporting requirements for GHG emissions and volatile organic compounds. • Flaring is a safety feature which reduces VOC emissions in event of safety-related trigger. • Techniques to minimize greenhouse gas emissions include carbon removal (*e.g.*, use of chemical stripping agents to absorb and desorb the carbon dioxide from the exhaust) and carbon capture (*e.g.*, injection to disposal well). • The recent Deep Panuke Project involves capturing and injecting CO_2 and H_2S into a deep aquifer disposal well thereby reducing GHG and atmospheric emissions.	• Carbon removal and capture technology requires further research for offshore application. • No alternative to fossil fuels is presently available for operating power systems on offshore platforms.	• Conduct research on offshore application of carbon removal and capture technology, including review of Deep Panuke injection of waste gas into reservoir. • Explore alternative energy sources for offshore use.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Petroleum Transportation (Pipelines and Tankers)	• Participants expressed concerns about damage from laying pipelines and loss of fishing access, although this issue was not given a lot of attention since production and transportation were not the focus of the panel review.	• Canadian and international standards for oil tankers are phasing out the use of single hulled vessel and older vessel types in favour of double hulled tankers. There has been a significant reduction in tanker accidents in the past thirty years. • Multibeam and other survey methods provide significant improvements in seabed mapping which reduce risks in selecting subsea systems locations and pipeline routes to avoid unstable topography and challenging geological formation. • Improved seabed mapping capabilities will improve pipeline routing to avoid challenging geologic formations and assess areas of sensitive biological habitat.	• Interpretation of multibeam data for Georges Bank would be required to refine habitat mapping and inform site selection to avoid sensitive habitats and geological risks.	• Continue work on interpretation of multibeam data to identify sensitive benthic habitats and geological risks.

Table 3.1 Summary of Residual issues Related to Technologies

Issue	1999 Panel Issue/ Concern	Technological Update	Residual Issue	Research Recommendation
Accidental Events	• Blowouts and spills could result in contamination of the marine environment and damage to marine populations.	• Training and qualification standards for offshore personnel have been developed and implemented by the Industry to improve operations and safety. • Annual spillage from exploration, production, and transportation has decreased dramatically due to improved technology and practices (API 2009; CNSOPB; C-NLOPB; ITOPF 2008). In particular, annual spillage from exploration and production has decreased from 30,400 bbl/year between 1969 -1977 to 3,900 bbl/year between 1998-2007 (API 2009). • Production oil spillage accounts for less than 0.9% of amount released from natural seeps (9,938 bbls vs 1,123,000 bbls from seeps annually from 1998 to 2007) (API 2009). • Fate and effect models are being continuously improved and can be used to support risk assessment studies, contingency planning, and clean-up operations.	• In spite of technological advances, the risk of a spill, albeit remote, will always remain. • Spill response measures are site and project-specific. Ongoing research and learnings from other spill events will serve to inform decision making.	• Develop and validate oil spill countermeasures for use on sensitive habitats such as Georges Bank. • Develop acceptable endpoints for clean up (*i.e.*, how clean is clean?).

In summary, a substantial amount of technological innovation has occurred in the offshore oil and gas sector worldwide over the last ten years. The last decade has brought considerable oil and gas experience to Atlantic Canada in the form of exploration and production activities, none of which, based on the results of EEM, have demonstrated population level effects to the marine ecosystem, or on species at risk and their critical habitat (CNSOPB 2009; Hurley and Ellis 2004). Although there are some residual risks identified by the 1999 Review Panel which remain to some extent in spite of technological advances, it is not realistic to assume that all risks can be mitigated by technological advances alone.

As best available technology continues to evolve, improvements in regulatory requirements, along with monitoring and adaptive management efforts and research and development in the context of environmental effects and mitigation, will also serve to minimize risks and issues of concern.

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APPENDIX A
TERMS OF REFERENCE

Project # OEER 300-180-Oct9B

Invitation for Commercial Proposals

An Assessment of Existing and Emerging Technologies and Mitigative Measures - Focusing on Georges Bank

for the

Offshore Energy Environmental Research Association (OEER)

I. OEER MANDATE AND SITUATION OVERVIEW

1.1 Mandate

The OEER was established in March 2006, to promote and fund research on energy and the marine environment. Current membership includes St. Francis Xavier University, Cape Breton University, Acadia University and the Nova Scotia Department of Energy.

The mission of OEER is to foster research and development related to offshore petroleum and renewable energy resources and their interaction with the marine environment and the diffusion of that knowledge, including the assessment of the potential impacts of:

(i) petroleum exploration, development and production; and
(ii) renewable energy technologies - exploiting ocean currents, wind, tides and waves

on the marine environment and, where consistent with these goals, to encourage building research capacity in Nova Scotia.

1.2 The need for a technical assessment of modern mitigation measures for drilling and production

Georges Bank is a large submarine bank (250km by 150km – 40,000 km^2) at the edge of the Atlantic continental shelf between Cape Cod and Nova Scotia. It is within the Bay of Fundy and Gulf of Maine tidal system, and is located approximately 100km offshore.

Georges Bank is a very biologically productive region. It is an area of high concentrations of Plankton and as a result, Georges Bank has historically sustained large stocks of fish such as herring, haddock and cod, as well as scallops. In the 1960s and 1970s, it was severely overfished by foreign trawling fleets from the former Soviet Union and Poland, depleting the stocks. In 1984, a boundary decision awarded 5/6 of Georges Bank to the U.S., with the easternmost 1/6 (7000 km^2 rich in ground fish and scallops) being awarded to Canada. Properly managed, it is estimated that the entire Georges Bank can sustain annual fishery yields of about 420,000 t, with easy access to ports.

Oil exploration companies in the 1960s and 1970s, along with the Geological Survey of Canada, estimated that the seafloor beneath Georges Bank possesses large amounts of petroleum reserves. The Canadian portion has been thought to be more prospective than the U.S. portion. Estimates on potential for discoveries vary and research efforts to update reserve estimates are expected to be undertaken shortly using modern software to interpret historical seismic data.

The Georges Bank represents an important ocean area to Canada from a broad social, economic and environmental perspective. On December 22, 1999, the Minister of the Nova Scotia Petroleum Directorate and the Minister of Natural Resources Canada announced that the Georges Bank moratorium would be extended until December 31, 2012. This decision was based on the recommendation of a three-member Public Review panel. **Click here to download a copy of the 1999 Georges Bank Review Panel Report.**

In March 2008, the Nova Scotia Department of Energy provided OEER with a $500,000 grant to support OEER research on matters specific to Georges Bank.

1.3 Purpose of the Project

The purpose of this study is to conduct an assessment of technologies and practices in offshore exploration, drilling and production that have been developed or are emerging since the 1999 Georges Bank review. Specifically, the study will assess the reliability of the technologies and practices, and their effectiveness in assuring that predicted environmental risks are adequately addressed and mitigated.

The study must identify the highest standards in technology and best practices that are currently used nationally and internationally in highly sensitive offshore areas or that are in the planning stages.

The study will also provide an assessment and summary of possible areas of research that may be required to better understand the potential impacts of these new or emerging technologies/practices, and if/how they may or may not be suitable for application in the Georges Bank area.

II. REQUIREMENTS

2.1 Time-Frames

The following schedule is presented for guidance:

(a) Deadline for Proposal Submission: 4:00 pm AST, October 23, 2009
(b) Preferred commencement date: November, 2009
(c) Completion date: February, 2010
(d) Submission of the written report: February, 2010
(e) Session to present research findings Spring, 2010

2.2 Objective

The objective of this Invitation for Commercial Proposals is to obtain the services of a consultant(s) to prepare a report to assist governments in their decision as to whether they should order a Public Review of the moratorium on petroleum activities on Georges Bank and if they should so order, to provide a preliminary body of information for use in the Public Review.

2.3 Scope of work

Scope: Geographic Location

The study area will be the Canadian portion of the Georges Bank region.

Scope: Activities

The assessment and subsequent report will incorporate the following:

- Building upon the risks identified in the 1999 Georges Bank Review Panel Report and reference documents and its identification of mitigation measures, assess the current state of knowledge with respect to reliability and effectiveness of existing and emerging technologies and offshore practices – particularly those used in environmentally or ecologically sensitive or important areas. Such technologies and practices should be in use or proposed to be in use nationally or in comparable international jurisdictions to mitigate environmental impacts in the following areas:

  - Seismic methods and technologies including alternative technologies for acquisition of seismic/resource data including coherent and non-coherent sources;
  - Produced water treatment and discharge;
  - Oil spill prevention, preparedness and response;
  - Drilling methods, such as slant and horizontal drilling that enable explorers to avoid sensitive habitats;
  - Drill cuttings and drilling muds;
  - Petroleum transportation options (identify which technologies and options are least intrusive);
  - Pipeline technology (identify which technologies and options are least intrusive); and
  - In any other area identified in the 1999 Georges Bank Panel Review process.
  - Identify any new problem areas or risks that have arisen since the 1999 Panel Hearings and to take these into consideration as well as those identified in the Panel Report when assessing the current state of knowledge surrounding the existing and emerging petroleum technologies.

Propose multidisciplinary research that should be undertaken to help address any of the knowledge gaps identified.

2.4 Deliverables

The successful bidder will be required to submit monthly progress reports to OEER including the following:

- Work completed to date.
- Accounting of expenditures - percentage of budget expended.
- Estimated time remaining to complete overall work.
- Identification of any issues to be resolved.
- Input required from other parties to enable the work to progress on time and on budget.

Upon completion of the written report, the successful bidder will deliver a presentation to OEER and its stakeholders on the outcomes of the report. **This will take place in the in the spring of 2010.**

2.5 Level of Effort

The suggested level of effort for this project is a maximum of $150,000.

2.6 Enquiry Contacts

A list of reference documents will be provided to assist consultants in responding to the request for proposals.

Proponents requiring further information on this Invitation for Commercial Proposals should contact:

Name:	Jennifer Matthews
Address:	OEER Association c/o 5151 George Street, Suite 400 Halifax, NS B3J 3P7
Telephone:	902-424-2493
Fax:	902-424-0528
Email:	oeer@offshoreenergyresearch.ca

III. EVALUATION CRITERIA

The following criteria, shown in order of importance, form the basis upon which evaluation of proposals will be made.

3.1 Mandatory Criteria

The following are mandatory requirements. Proposals not meeting them will receive no further consideration during the evaluation process:

- All information requested in this Invitation for Commercial Proposals must be provided;

- All proposals must be submitted in Canadian Dollars (CDN) exclusive of all taxes;
- The consultant must be able to demonstrate experience with the requirements identified in Sections 2.2 and 2.3;
- The consultant must be able to demonstrate relevant knowledge and experience relating to Nova Scotia's offshore petroleum activities; and
- The consultant must be able to demonstrate that they can meet the required completion date.

3.2 Desirable Criteria

The following criteria will be evaluated for all proposals that satisfy the mandatory criteria. Please include this table in your proposal and insert references to the appropriate pages or sections of your Proposal that deal with the subjects under evaluation.

Factor	Weight	Reference Proposal Page/Section
Experience and Capability • Experience with and knowledge of petroleum industry technologies and practices • Experience in conducting technology risk assessments • Knowledge of the Georges Bank moratorium and related issues • Experience with Nova Scotia stakeholders and regulatory processes • Proponents have the necessary qualifications and capacity to undertake the prescribed work	25	
Approach and Methodology • The proponent demonstrates a clear understanding of OEER's needs and has proposed an approach and methodology that will enable the successful completion of the objectives. • The proponent has identified potential challenges to meeting objectives, and has provided a plan for overcoming risks.	25	
Project Management • The proponent has outlined a clear and effective management plan that will ensure timely delivery of results and proper accountability for all project tasks.	25	
Cost • The project will offer very good value for the proposed budget. • The project budget is complete and well described (i.e. includes salaries, travel and accommodations, report preparation, other associated costs).	20	
Other • The proposal is well-written. • The reviewers are overall satisfied with the proposal, attention to needs, expected deliverables, deadlines and cost.	5	

IV. PROPOSAL CONTENT AND RESPONSE GUIDELINES

In order to receive full consideration during evaluation, proponents must adhere to the following:

4.1 Submit in Electronic Form

Proposals are to be written using the attached OEER proposal form (see **Schedule "A"**).

Proposals must be submitted in electronic form by **4:00 pm AST, October 23, 2009, to Jennifer Matthews, oeer@offshoreenergyresearch.ca.**

Late proposals will be rejected.

4.2 Proposal Content

Proposals must be submitted on the proposal form in Schedule A and in order to receive full consideration proposals should address the following:

- **Understanding of the Requirements**
  Proposal must demonstrate understanding of the OEER requirements.
- **Definition of the Research Objectives to be addressed**
  Generally describe how the proposal addressed the specific and relevant research objectives of OEER.
- **Experience and capabilities**
  Provide details of work and experience as outlined in Schedule A.
- **Outline of the Approach and Methodology**
  Describe the proposed project approach and methodologies that will used to enable the successful completion of the objectives.
- **Proponent Profile and Team**
  Identify all personnel who will be assigned to the project and who will contribute to (a) the routine management and/or (b) the performance of the required services.
- **Work Plan**
  A work plan should be presented which ties in with the research approach and specifies both begin and end dates, as well as key delivery dates for specified deliverables. Outline a clear and effective management plan that will ensure timely delivery of results and proper accountability for all project tasks.
- **Proposal Pricing**
  Pricing values must be included as outlined in Schedule A.

V. PROPONENT CHECKLIST

This checklist has been provided solely for the convenience of the proponent. Its use is not mandatory and it does not have to be returned with the proposal.

- The requirements of the Invitation for Commercial Proposals have been read and understood by everyone involved in putting together the proposal.
- The proposal explicitly addresses everything asked for in the Invitation for Commercial Proposals.
- The proposal meets all the mandatory requirements of the Invitation for Commercial Proposals.
- The proposal clearly identifies the proponent, the project, and the Invitation for Commercial Proposals.

APPENDIX B
CONCORDANCE TABLE

* Used RFP Activities (Invitation for Commercial Proposals: An Assessment of Existing and Emerging Technologies and Mitigative Measures - Focusing on Georges Bank for the Offshore Energy Environmental Research Association (OEER) (Project # OEER 300-180-Oct9B)

Table B1 Table of Concordance

RFP REQUIREMENTS	STANTEC REPORT
Section 1.3 RFP: Purpose of the Project	
The purpose of this study is to conduct an assessment of technologies and practices in offshore exploration, drilling and production that have been developed or are emerging since the 1999 Georges Bank review. Specifically, the study will assess the reliability of the technologies and practices, and their effectiveness in assuring that predicted environmental risks are adequately addressed and mitigated.	Section 1
The study must identify the highest standards in technology and best practices that are currently used nationally and internationally in highly sensitive offshore areas or that are in the planning stages.	Section 2
The study will also provide an assessment and summary of possible areas of research that may be required to better understand the potential impacts of these new or emerging technologies/practices, and if/how they may or may not be suitable for application in the Georges Bank area.	Section 3
Section 2.3 RFP Scope: Geographic Location	
The main study area will be the Canadian portion of the Georges Bank region.	Section 1
Section 2.3 RFP Scope: Activities	
The assessment and subsequent report will incorporate the following:	
Building upon the risks identified in the 1999 Georges Bank Review Panel Report and reference documents and its identification of mitigation measures, assess the current state of knowledge with respect to reliability and effectiveness of existing and emerging technologies and offshore practices – particularly those used in environmentally or ecologically sensitive or important areas. Such technologies and practices should be in use or proposed to be in use nationally or in comparable international jurisdictions to mitigate environmental impacts in the following areas:	Section 2
• Seismic methods and technologies including alternative technologies for acquisition of seismic/resource data including coherent and non-coherent sources;	Section 2.1
• Produced water treatment and discharge;	Section 2.3
• Oil spill prevention, preparedness and response;	Sections 2.6
• Drilling methods, such as slant and horizontal drilling that enable explorers to avoid sensitive habitats;	Sections 2.2

Table B1 Table of Concordance

RFP REQUIREMENTS	STANTEC REPORT
• Drill cuttings and drilling muds;	Section 2.2
• Petroleum transportation options (identify which technologies and options are least intrusive);	Section 2.5
• Pipeline technology (identify which technologies and options are least intrusive);	Section 2.5
• In any other area identified in the 1999 Georges Bank Panel Review process; and	Section 2.4
• Identify any new problem areas or risks that have arisen since the 1999 Panel Hearings and to take these into consideration as well as those identified in the Panel Report when assessing the current state of knowledge surrounding the existing and emerging petroleum technologies.	Section 2
Propose multidisciplinary research that should be undertaken to help address any of the knowledge gaps identified.	Section 3

APPENDIX C
REGULATORY CONTEXT

1.0 Regulatory Context

1.1 PRESENT REGULATORY CONTEXT

During the Panel Review process, there were three main themes of discussion related to the regulatory regime: 1) the stringency or effectiveness of regulatory requirements and the science on which decisions are based; 2) consultation and liaison practices; and 3) compensation issues.

Since the Panel review of the moratorium in 1999, there has been significant maturation of the offshore industry in Nova Scotia. For example, in 1999, two production licenses were issued by CNSOPB for LASMO's Cohasset and Panuke light oil production facility. By 2008, eight production licenses had been issued and the Sable Offshore Energy Program is currently in production. In 2007, EnCana's Deep Panuke project passed the regulatory approval process and the project is now in development (Stantec 2009). The revisions to the guidelines and regulations since 1999 reflect the lessons learned by both the operators and the regulators as these major projects have matured. The issues raised by the 1999 Georges Bank Panel Review in the context of technical development fall under the regulations and guidelines to which operators must abide.

Established in 1990, pursuant to the *Canada-Nova Scotia Offshore Petroleum Accord Implementation Act* and the *Canada-Nova Scotia Offshore Petroleum Accord Implementation (Nova Scotia) Act (Accord Acts),* the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) is the independent joint agency of the Governments of Canada and Nova Scotia responsible for the regulation of petroleum activities and resources offshore Nova Scotia. The CNSOPB's activities and decision making processes are guided by a regulatory framework which comprises legislation, regulations, guidelines, memoranda of understanding and other regulatory documents. This legislation would govern petroleum hydrocarbon development activities on Georges Bank should the moratorium be lifted.

In addition to the *Accord Acts*, there are a number of acts and regulations which provide legislative instruments to govern ocean-related activities and offshore petroleum development. These acts authorize the CNSOPB, DFO, Transport Canada and Environment Canada to make regulations with respect to their specific mandates and responsibilities for the purpose of protecting resources, human life and the environment. Regulations relevant to offshore petroleum development are listed in Table 1 with a summary of pertinent applications to the offshore.

Guidelines have been developed or adopted by CNSOPB which provide detailed procedures and practices for industry in accordance with the regulations to be followed. Table 2 lists the guidelines, most of which are updated regularly, for the offshore industry which are pertinent to this study. The industry may also follow requirements by other regulators or industry-related bodies. Two important examples are:

- Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (2007) developed by DFO; and
- Atlantic Canada Offshore Petroleum Industry Standard Practice for the Training and Qualifications of Personnel (2008) developed jointly by CAPP, CAODC, CNSOPB and C-NLOPB.

Both of these codes of practice have been adopted by the CNSOPB and are cited in their list of Guidelines.

On December 31, 2009, the CNSOPB released a number of draft guidelines (see Table 3.2) which are now available to stakeholders for review and comment over the next year. The CNSOPB also states that the issue of these guidelines is intended for “reference by interested parties to assist in the transition to the new goal-oriented Drilling and Production Regulations applicable in the Nova Scotia offshore area.” Although there may be alterations to these draft guidelines based on input from stakeholders, any alterations are likely to be directed to specific topics and will not alter the documents substantively. Therefore, it is prudent to consider these as the latest set of guidelines for the purposes of this study.

Table 1 Applicable Regulations for Offshore Petroleum Development

Regulation	Regulating Agency (Regulation No)	Application
Nova Scotia Oil and Gas Drilling and Production Regulations	CNSOPB (SOR/2009-315)	Regulations amalgamate and modernize Drilling Regulations and Production and Conservation Regulations under the *Canada Oil and Gas Operations Act* and the *Accord Acts*. These regulations govern the following: • production procedures to be followed by Operators with respect to drilling, constructing, operating and decommissioning a production well, • procedures to be followed on the installation with respect to safety and environmental issues, • procedures for measuring and recording volume and flow , • reporting requirements to CNSOPB during the operation of the well • other related activities conducted by the operator in conjunction with well
Fisheries Act and Bill C-32	DFO (R.S. 1985, c.F-14, 2007, (Fisheries Act,1985, Bill C-32, 2007)	Bill C-32, 2007, repeals and replaces the *Fisheries Act*. to include the following: • Provides for sustainable development of Canadian fisheries and fish habitat in collaboration with fishers, the provinces, aboriginal groups and other Canadians. • Considers fish habitat protection and pollution prevention as issues separate from fisheries management. • prohibits harmful alteration, disruption or destruction of fish habitat (HADD) unless this HADD has been authorized by the Minister of Fisheries and Oceans
Oceans Act	DFO (1996, C-.31)	The *Oceans Act* assigns DFO the lead role in integrated planning and management of ocean activities and legislates three main initiatives: Marine Protected Areas Program; Integrated Management Program; and Marine ecosystem health program.
Canadian Environmental Protection Act, 1999	EC (1999, C-.33)	*CEPA 1999* replaces the Ocean Dumping Regulations, 1988 and includes the following: • Prohibits the disposal of wastes and other matter (*e.g.,* dredged material) at sea within Canadian jurisdiction unless the disposal is done under a permit issued by the Minister of Environment. • Provides regulations to manage toxic substances, other pollution and wastes, including disposal at sea.
Species at Risk Act	EC (*SARA* 2002, C. 29)	*SARA* 2002 came into force in 2004 and requires project proponents to demonstrate that no harm will occur to listed species under the act, their residences or critical habitat. *SARA*-listed species do occur on Georges Bank, although no "critical habitat" for species at risk has been defined in the moratorium area.
Nova Scotia Offshore Petroleum Installation Regulations	CNSOPB (1995, SOR/95-191) (Current to Jan 25, 2010)	Comprehensive regulations that govern the design and engineering specifications required for offshore petroleum facilities to ensure safety of personnel, protection of the environment and to facilitate access to equipment.
Nova Scotia Offshore Certificate of Fitness Regulations	CNSOPB (1995, SOR/95-187)	Provides regulations requiring offshore drilling facilities, diving systems, accommodation facilities and production facilities to be certified by an approved Certifying Authority. Establishes the responsibilities and procedures to be followed in the certification process.
Canada- Nova Scotia Oil and Gas Spills and Debris Liability Regulations	CNSOPB (1995, SOR/95-123) (Current to Jan 25, 2010)	Establishes a limit of liability to the Operator of $30million with respect to debris or a spill associated with offshore oil or gas exploration or production.

Table 1 Applicable Regulations for Offshore Petroleum Development

Regulation	Regulating Agency (Regulation No)	Application
Nova Scotia Offshore Petroleum Geophysical Operations Regulations	CNSOPB (SOR/95-144)	Regulations govern the requirement for conducting seismic programs which include • Authorizations and responsibilities in conducting seismic surveys • Procedures to be used during operations for operation of various types of seismic sound sources • Occupational health and safety requirements • Reporting requirements during the conduct of the survey and reporting of the findings of the survey

Notes: CNSOPB = Canada - Nova Scotia Offshore Petroleum Board; NEB = National Energy Board; DFO = Fisheries and Oceans Canada; EC = Environment Canada:

Table 2 Applicable Guidelines for Offshore Petroleum Development Technologies

Guideline	Regulating Agency (Latest Date)	Application and Summary of Guideline Elements Related to Technology
Offshore Waste Treatment Guidelines	CNSOPB (August 2002)	**Applies to waste treatment technology, engineering design and operation procedures** Provides guidelines for practices and minimum standards for the treatment and disposal of wastes from petroleum drilling and production operations. Identifies sampling and analysis requirements for compliance with the standards. Establishes a five year review for procedures and standards. Provides revised prescribed limits to drill waste and produced water discharges for 2002.
Offshore Chemical Selection Guidelines for Drilling & Production Activities on Frontier Lands	CNSOPB (April 2009)	**Applies to drilling and production technology and engineering** Provides a framework for selecting chemicals which minimizes the potential for environmental impacts from offshore drilling and production operations. Promotes the selection of lower toxicity chemicals where technically feasible. Establishes a minimum five year review period to reflect significant gains in scientific and technical knowledge. Provides updates to other relevant legislation and international standards to guide the review and updates of the guidelines.
Drilling and Production Guidelines	CNSOPB (Draft, December 2009)	**Applies to technologies, methods and procedures to be followed for drilling and exploration or production well.** Provides comprehensive guidelines for the implementation of regulations for exploration and production. Outlines the Broads regulatory powers. Outlines the procedures and authorizations required for an approval and describes the duties of the Operator in managing a development. Describes safety and engineering standards to be followed for equipment and operations during exploration and development of an offshore well. Describes the procedures, standards and reporting requirements for the evaluation of a well or pool. Identifies the measurements to be made for production and injection. Describes the requirements for methods to be followed to maximize production from a pool or field. Provides specifications for support operations including vessels and helicopter and other equipment to comply with safety standards. Establishes competencies for personnel and the safety training g requirements and standards to be followed, standards and reporting requirements for the evaluation of a well or reservoir**.** Describes the required submissions, notifications, records and reports and the form in which they are to be proved to the Board by the Operator.

Table 2 Applicable Guidelines for Offshore Petroleum Development Technologies

Guideline	Regulating Agency (Latest Date)	Application and Summary of Guideline Elements Related to Technology
Environmental Protection Plan Guidelines	CNSOPB (Draft, December 2009)	**Applies to the technological resources , procedures and practices to be followed and monitoring requirements which are identified in the Environmental Protection Plan (EPP)** Establishes the requirements for an EPP which includes the identification of risks/hazards, standards to be met with regard to discharges and resources to be used to meet environmental objectives. Assigns roles and responsibilities for operations. Assigns responsibility to the operator for training and awareness of personnel. Identifies equipment systems and facility critical to environmental protection. Identifies the selection of approved chemicals and waste treatment /disposal practices. Identifies emergency response procedures to be followed assigned by the EPP.
Geophysical and Geological Programs in the Nova Scotia Offshore Area- Guidelines for Work Programs, Authorizations and Reports	CNSOPB (1992)	**Applies to all geophysical or geological field programs conducted in the Nova Scotia offshore** Establishes permitting and work authorization requirements. Establishes reporting requirements for field programs and additional requirements for 3D surveys. Describes the requirement for seabed (geo-hazard) surveys including; equipment to be used, coverage area, authorizations and reporting.
Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment	DFO (2007)	**Applies to all seismic programs in Canadian waters for the purpose of mitigating the impact of noise on marine receptors** Establishes safety zones, marine mammal observation requirements, soft-start procedures and restrictions for starting the seismic program.
Atlantic Canada Offshore Petroleum Industry Standard Practice for the Training and Qualifications of Personnel.	CAPP, CAODC, CNSOPB & C-NLOPB, (April 2008)	**Applies to training standards for personnel operating equipment offshore** Establishes the qualifications of personnel relevant to their responsibilities Establishes the chain of command and levels of authority in offshore operations Establishes minimum safety training programs for individuals working on offshore facilities.
Guideline for the Reporting and Investigation of Incidents	CNSOPB (June 2009)	**Applies to equipment failures and investigation of cause** Provide guidance for reporting offshore related incidents including environmental, health and safety incidents. Identifies those incidents which are considered to be reportable. Identifies the Boards expectations for investigation and follow up to be conducted by the Operator. Provides criteria for safety performance measurement and statistical parameters to be reported.
Offshore Physical Environmental Guidelines	CNSOPB (September 2008)	**Applies to equipment to measure environmental data as required by regulations.** Provides lists of equipment approved for use.

Table 2 Applicable Guidelines for Offshore Petroleum Development Technologies

Guideline	Regulating Agency (Latest Date)	Application and Summary of Guideline Elements Related to Technology
Measurement Guidelines	CNSOPB (October 2003)	**Applies to equipment required to measure the quantities of petroleum production at a field.**

Notes: CNSOPB = Canada - Nova Scotia Offshore Petroleum Board
C-NLOPB = Canada – Newfoundland and Labrador Offshore Petroleum Board
CAODC = Canadian Association of Oilwell Drilling Contractors
CAPP = Canadian Association of Petroleum Producers
DFO = Fisheries and Oceans Canada
EC = Environment Canada
NEB = National Energy Board

1.2 REGULATORY CHANGES

Although there are a number of guidelines which apply to technologies selected for offshore operations, there are four main guidelines or codes of practice which have significant influence on the engineering technologies applied to exploration and drilling programs. Changes to these guidelines are significant to the engineering technologies applied in offshore programs. These guidelines are:

- Offshore Waste Treatment Guidelines (OWTG), August 2002 is the latest revision;
- Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (2007);
- Drilling and Production Guidelines, DRAFT issue December 31, 2009; and
- Offshore Chemical Selection Guidelines for Drilling & Production Activities on Frontier Lands, April 2009.

These guidelines apply to both exploration and production activities involving drilling.

1.2.1 Offshore Waste Treatment Guidelines (OWTG)

The OWTG apply to two important waste discharges from drilling and production; the discharge of muds and cuttings from drilling operations and produced water discharges, which are typically part of production operations. The following sub-sections are reviews of present guidelines, the history of the guidelines covering produced water and drill mud and cutting in Canada and reviews of the guidelines used in other jurisdictions.

1.2.1.1 Produced Water Guidelines

Another important revision to the OWTG was the limit established for produced water discharges. Production installations commencing operation in 2002 or later need to ensure that the 30-day weighted average of oil in discharged produced water does not exceed 30 mg/L and that the 24-hour arithmetic average of oil in produced water does not exceed 60 mg/L. The 1996 version of the Guidelines had limits of 40 mg/L (averaged over a 30-day period) and 80 mg/L (averaged over a 48-hour period) (NEB *et al.* 1996). Installations which had started production previous to 2002 (*e.g.,* SOEP) were expected to achieve a 30-day weighted average of oil in discharged produced water of 30 mg/L no later than December 31, 2007 (NEB *et al.* 2002a).

Table 3 summarizes the guidelines for produced water discharges which have been adopted in other jurisdictions. Canada's Produced Water Guidelines are similar to those of other countries.

Table 3 Summary of Produced Water Regulations/Guidelines in Key Countries

Country	Oil in Water Limit
Australia	The concentration of petroleum (dispersed) in any produced water discharged to the sea is not to exceed 50 mg/L at any one time and average less than 30 mg/L during each period of 24 hours.
Brazil	Oil in water content recommend to be a maximum of 20 mg/L.
Canada	The Offshore Waste Treatment Guidelines for Atlantic Canada (NEB *et al.* 2002a) recommend that oil concentrations in produced water not exceed a monthly average of 30 mg/L and a daily average of 60 mg/L.
North Sea[1]	The Oslo–Paris Commission (OSPAR 2001) set recommended waste treatment guidelines for produced water discharges of hydrocarbons in the OSPAR signatory states at a monthly average of 30 mg/L, effective beginning in 2006 (no exceptions threshold noted).
Norway[1]	The Oslo–Paris Commission (OSPAR 2001) set recommended waste treatment guidelines for produced water discharges of hydrocarbons in the OSPAR signatory states at a monthly average of 30 mg/L, effective beginning in 2006 (no exceptions threshold noted).
United Kingdom[1]	The Oslo–Paris Commission (OSPAR 2001) set recommended waste treatment guidelines for produced water discharges of hydrocarbons in the OSPAR signatory states at a monthly average of 30 mg/L, effective beginning in 2006 (no exceptions threshold noted).
United States	The offshore sub-category effluent guidelines limit oil and grease in produced water discharges to an average of 29 mg/L and a maximum of 42 mg/L, based on best available technology.

[1] The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) governs the discharge of offshore discharges wastes in the waters of the OSPAR signatory states: Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland. This was first set to 40 mg/L oil in water content for produced water discharges; however as of 2006, it was lowered to 30 mg/L.

1.2.1.2 Drilling Mud and Cuttings Guidelines

The OWTG (NEB *et al.* 2002a) outline recommended practices and standards for the treatment and disposal of wastes from petroleum drilling and production operations in Canada's offshore areas, and for sampling and analysis of waste streams to ensure compliance with these standards (NEB *et al.* 2002a). These Guidelines are reviewed and updated approximately every five years and are currently under review by the three Boards with input from stakeholders. The key updates in the 2002 revision included a concentration limit of 6.9 g/100 g or less oil on wet drill solids.

At the time of the Georges Bank Panel Review, the 1996 version of the Guidelines were being used, which included a requirement of treatment of drill waste to reduce oil concentrations to 15 g/100 g or less of dry solids (NEB *et al.* 1996). Between the 1996 and 2002 versions of the Offshore Waste Treatment Guidelines, a 1% discharge limit was implemented in 2000. This 1% discharge limit essentially represented a zero discharge regime for oil-based muds, resulting in operators “skipping and shipping” the drill waste to shore for land disposal. The limit was changed to 6.9% in 2002 based on an understanding of best available technology and environmental effects monitoring results which had demonstrated a lower impact level than previously assumed during environmental assessments of drilling projects (refer to Section 2.2.3 for more information on scientific advancements related to drill waste).

The International standards and regulations for drilling mud discharges for key countries are summarized in Table 4 below. These standards not only demonstrate acceptability and tolerance for oil and gas activities around the world, but also demonstrate the extent of industry capabilities where regulations may be more stringent than in Canadian jurisdiction (*e.g.,* zero discharge).

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
Australia	• Discharge allowed subject to 1% oil limit, including free oil & diesel oil, and 17% KCl content of muds for exploratory drilling. Sampling required predischarge. • Other drilling wastes can be discharged as long as they meet the 1% oil limit. • Risk assessments required by regulator. • Operators describe the types of muds to be used and may make commitments for additional testing or monitoring in Environment Plans which are submitted to the government and once accepted become binding requirements. • Flow rate monitored but not reported or limited. • Some dischargers monitor Hg/Cd.	• 1% oil limit effectively eliminates discharge. In W A, operators were allowed approx. 15% oil limit for low tox OBM cuttings 2-3 years ago. This exception would most likely not be allowed now. • Restriction on fluids with aromatics >1%. • At present, in Western Australia (WA) over 80% of all wells are drilled using WBF in all hole sections. The remaining wells are drilled using WBF for the top hole sections and non-WBF in the 311 mm (12 1/4 inch) and/or 216 mm (8 1/2 inch) bottom hole sections. The use of low toxicity OBF in the bottom hole sections has reduced from 10% of all wells drilled in 1994 to 0% (as of mid-1998). The use of SBF has remained essentially the same over the same period with increasing proportion of EBFs. Since the late 1980s there has been a trend towards the increased use of more technically advanced WBFs.	• No specific regulatory language concerning SBM. • WA regulator sets a 10% dry weight limit on SBM cuttings discharges under environmental plan regulations. • Operators have discharged esters and IO cuttings with requirements for monitoring programs determined on case by case basis. • Esters seem to be acceptable but more general acceptability of SBM not resolved. • Environmental regulations for offshore E&P being overhauled and may become more detailed and specific. • Enhanced-mineral-oil-based cuttings have been used in the past in WA and discharged. • Where the use of SBF is accepted, discharges to the seabed are limited to a maximum amount of 10% by dry weight of base fluid on drilled cuttings for a 311 mm (12 1/4 inch) hole size	• Monitoring not required but may be in the future. • Operators may make commitments for monitoring in environment Plans which are submitted to the government and once accepted become binding requirements.

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
Brazil	• No specific regulatory language concerning WBF. • Current practice is to allow discharge.	• All drilling discharge plans need to be approved through IBAMA,; IBAMA has made it clear that there will be greater scrutiny of NAF discharges (than those of WBFs) • OBM not permitted for discharge. • Unlikely that low tox mineral oils would be approved- Enhanced Mineral Oil-based fluids possible. • Petrobras presently discharging a highly refined paraffin mud.	• SBM cuttings have been discharged by Petrobras. • Industry workgroup formulated guidelines for discharge approval (laboratory testing protocols-biodegradability, sediment toxicity, and bioaccumulation) and worked with government to develop a framework for gaining approval for use of synthetics. • Zero discharge in <60m water depth and environmentally sensitive areas; Monitoring requirements that vary by depth; >1000 m: no monitoring required; 60 - 1000 m: comprehensive water column and seabed monitoring; NADF (SBM) cuttings permitted for discharge in water depths >60 m subject to pre and post drill toxicity tests on organisms from four different phyla and lab tests of NABF for biodegradation (OECD 306 method), total PAH concentration, and bioaccumulation potential (log Pow).; average <9.4%ROC for ester, average <6.9%ROC for paraffin/olefin, Hg/Cd in barite <1/3 mg/kg; <1% formation oil (by RPE).	

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
Canada	• The 2002 Offshore Waste Treatment Guidelines allow the discharge of water-based muds without restrictions but encourage operators to reduce the need for bulk disposal of drilling fluids. • Discharge of drill cuttings associated with WBMs are also permitted.	• 2002 Offshore Waste Treatment Guidelines require approval by the Chief Conservation Officer for the use of OBMs, when it is not technically feasible to use WBMs or SBMs. • This only occurs under exceptional circumstances and at no time can whole OBMs be discharged to sea. • The Chief Conservation Officer may grant approval for the use of enhanced mineral oil-based muds (EMOBM) provided it's environmental and safety performance can be demonstrated to be equivalent or better than SBM. • Whole EMOBM are not permitted to be discharged at sea, instead they must be recovered and recycled, re-injected, or transferred to shore to be treated and disposed of using an approved method.	• 2002 Offshore Waste Treatment Guidelines require SBMs to have a PAH concentration of < 10 mg/kg and be able to biodegrade under aerobic conditions. • Whole SBM are not permitted to be discharged at sea, instead they must be recovered and recycled, re-injected, or transferred to shore to be treated and disposed of using an approved method and must have a PAH content of < 10 mg/kg. • Drill cuttings associated with SBMs are to be re-injected and where this option may not be technically feasible the cuttings may be discharged at sea provided they have been treated first with the best available technology (BAT) first to achieve a oil on cuttings retention limit of 6.9% wet weight.	• Environmental Effects and Compliance Monitoring are required for production drilling per the Offshore Waste Treatment Guidelines.

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
		• Drill cuttings associated with OBM are not permitted to be disposed of at sea, however drill cuttings associated with EMOBM are permitted to be disposed of at sea provided they have been treated with best available technology to achieve an oil on cuttings retention limit of 6.9 % wet weight.		
North Sea	• Discharge of WBM is permitted given that the oil content is less than 1% by weight and that it has passed toxicity testing under OSPAR 2000/3. • Persistency (P): Half-life (T½) of 50 days and • Liability to Bioaccumulate (B): log Kow>=4 or BCF>=500 and • Toxicity (T) Taq: acute L(E)C50=<1 mg/l, long-term NOEC=<0.1 mg/l	• The discharge of OBM on cuttings is limited to 1% by weight.	• The discharge of SBM on cuttings exceeding 1% SOC is only permitted under exceptional circumstances.	

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
Norway	• Discharge allowed subject to pre-approval requirements for all drilling fluid chemicals. • Monitoring of discharge sites may be required. Preapproval requirements include toxicity testing according to OSPAR protocols. • No KCl limits. • Flow rate not monitored or limited, but calculation is made of cuttings discharged based on well dimensions and wash out factor. • Sampling is daily. • Discharge of other drilling wastes not prohibited as long as pre-approval occurs. • A discharge permit is required for cementing and completion chemicals. • Drilling must makeup is monitored and reported.	• Under OSPAR 2000/3, discharge is subject to limit of 1% oil on cuttings with is not operationally attainable with current technology.	• Permitting discharge of a range of synthetics for development drilling only. • SBM discharge allowed only where technical/safety considerations preclude use of WBM. • SBM content of cuttings limited to 8-18%; operator is required to set limit based on properties of formation. • Chemical monitoring of cuttings required annually, biological monitoring required every 3 years. • Applications for approval require testing according to OSPAR format. • OSPAR decision 2000/3 permits Group III cuttings discharge only under exceptional circumstances (for Norway, likely to mean only at those sites where SBFs have been previously discharged.	• A baseline survey is required prior to initiation of production drilling activities. • Monitoring activities are thereafter required to be performed every 3 years. Surveys involve sampling of sediment and analysis for biological and chemical properties. • Guidelines for monitoring are provided in the 1999 SFT document "Environmental monitoring of petroleum activities on the Norwegian shelf; guidelines" (in Norwegian) • Guidelines for characterizing drill cuttings piles have been prepared by the Norwegian oil industry association (OLF)

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
United Kingdom	• Discharge allowed subject to pre-approval requirements for drilling fluid chemicals. Pre-approval requirements include toxicity testing according to OSPAR protocol.	• Limit of 1% oil on cuttings- effectively prohibits discharge • Practice is to inject cuttings or return to shore and recover oil.	• Phasing out use of all but ester based synthetics. Industry expects further restrictions on esters. Discharge of non-ester fluids will likely ceased at end of 2000. • Although OSPAR 200/3 decision permits Group III cuttings discharge only under exceptional circumstances. • The UK government has made it clear that there will be no exceptional circumstances arising that would lead to discharge of SBM cuttings.	• OSPAR requirements • Requirements for seabed monitoring following discharge of SBM cuttings; data used in conjunction with laboratory data to determine fluid acceptability.
United States	• **Coastal Waters:** (e.g. inland canals and enclosed bays). Discharge prohibited except for Alaska. Alaskan coastal waters subject to same regulations as offshore waters. • **Offshore Water (California):** • Discharge allowed beyond coastal waters (3 mi). • 50lb/bbl in EPA generic mud #1. • Flow rate is monitored and maximum annual discharge cannot exceed 215,000 bbl. • 96hr LC50 SPP >3%. Weekly sampling; at least 1 tox. Test of each mud system. Mud sample must be at 80% or greater of final depth for each mud system. • Hg/Cd <1/2 ppm.	• **California:** Discharge of enhanced-mineral-oil-based mud/cuttings prohibited. Practice is to inject OBM cuttings. • **GOM:** Discharge not allowed. OBM cuttings are typically landfilled. Exxon typically rents OBM pay for the volume that is not returned. Cuttings are treated to carrying degrees onshore and either injected or landfilled.	• **GOM:** Only SBM associated with cuttings may be discharged. Subject to the essentially the same restrictions as WBM. Currently, spills of SBM are treated as oil spills. Additional restriction of no discharges within 544 m of Areas of Biological Concern (Central and Western GOM) and within 1000 m of Areas of Biological Concern (Eastern GOM). • **California:** Not specifically mentioned in current permit. Under discussion for regional permit. • EPA is developing specific guidelines for SBM cuttings discharge.	• **GOM:** Compliance monitoring as detailed. No requirements for routine scabbed monitoring.

Table 4 Summary of Requirements for Discharge of Drilling Mud and Cuttings in Key Countries (Modified from Stantec 2009)

Country	Water-Based Drilling Fluids and Cuttings	Oil-Based Drilling Fluid Cuttings	Synthetic-Based Drilling Fluid Cuttings	Environmental Monitoring Requirements
	• No free oil/diesel/waste oil as by static sheen test. • No chrome lignosulfonate. • Spotting fluids must meet toxicity requirements. • Drilling mud makeup monitored and reported. • Special restrictions for environmentally sensitive areas. • **Offshore Water (GOM):** • Discharge allowed >3 miles, not allowed <3 miles. • Flow rate is estimated hourly during discharge. • Toxicity testing monthly. By Exxon choice, testing every time mud system changed. Static sheen testing is performed weekly. •			

1.2.2 Codes of Practice for Seismic Exploration

In 2007, in response to concerns from many stakeholders regarding the issue of noise impacts associated with seismic airguns on the marine environment, DFO established a code of practice to be followed by seismic operators. The elements of these guidelines control practices rather than the technology. For example, during seismic surveys measures to be taken include:

- Provide a safety zone of a minimum 500 m radius around the airgun array;
- Provide a qualified Marine Mammal Observer (MMO) to visually monitor the safety zone at least 30 minutes prior to starting the airguns and during all periods when the airguns are being used above the threshold noise value established under *CEAA;*
- Airguns can only be started if the MMO has not identified species which might be adversely effected are not within the safety zone; and
- A 20-minute period will be used to gradually start or "ramp-up" to airguns before full operations begin.

These procedures provided mitigation of environmental concerns identified in 2004 by DFO in its *Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates and Marine Turtles and Marine Mammals.* This study examined available information on impacts to marine species from seismic programs, identified potential physiological and behavioural effects which could have negative impacts on some species and identified significant gaps in available research on the subject.

Historically in eastern Canada, offshore seismic programs have followed the CNSOPB *Geophysical and Geological Programs in the Nova Scotia Offshore Area - Guidelines for Work Programs, Authorizations and Reports* issued in 1992. These guidelines applied to all seismic programs related to exploration and identified the authorization and reporting requirements. In addition, these guidelines established the criteria to be followed and equipment to be used in geo-hazard site surveys. Regulations governing seismic programs for the Oil and Gas sector are contained in the *Nova Scotia Offshore Petroleum Geophysical Operations Regulations.* These regulations were introduced in 1995 and are considered current to January 25, 2010. The applicable elements of these regulations are described in Table 1.

In many respects, international standards for seismic exploration are quite consistent. Table 5 (adapted from Tsoflias and Gill 2008) lists the regulations, including consideration of species of concern, and ramp up and shut down procedures for seven countries. In addition to the information in the table, the following procedures are required for all seven countries:

- Qualified observers, or in the case of New Zealand a marine mammal coordinator;
- A pre-survey observation period;
- A soft-start ramp up procedure;
- A shut-down procedure when a species of concern enters the shutdown zone;
- Except for New Zealand, nighttime or low-visibility procedures; and
- Passive acoustic monitoring, although only required in the United Kingdom in sensitive areas, is encouraged in all jurisdictions, except for Ireland.

Table 5 Summary of Mitigation Measures for Seismic Operations in Key Countries (Modified from Tsoflias and Gill 2008)

Country	Regulation	Species Protected by the Regulations	Ramp up Restrictions	Shut down Requirements
Australia	• EPBC Act Policy Statement 2.1- Interaction between offshore seismic exploration and whales (2007)	• Whales excluding smaller dolphins and porpoises	• 30 min. pre-survey observation period • Initiate soft-start with lowest energy-output/volume airgun • Gradually add airguns over 30 min • Continuous visual observations required	• 500 m shutdown zone
Brazil	• Guide for monitoring marine biota during seismic data acquisition activities (2005)	• Marine mammals and sea turtles	• 30 min. pre-survey observation period • Initiate soft-start with lowest energy-output/volume airgun • Gradually add airguns over 20-40 min	• 500 m shutdown zone
Canada	• Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (2007)	• Marine mammals and sea turtles	• 30 min. pre-survey observation period • Initiate soft-start with lowest energy-output/volume airgun • Gradually add airguns over 20-40 min	• 500 m shutdown zone
Ireland	• Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters (2007)	• All cetaceans	• 30 min. (depth<200 m) and 60 min. (depth>200 m) pre-survey observation period • Initiate soft-start with smallest airgun • Gradually add airguns over 20-40 min	• 1,000 m shutdown zone
New Zealand	• Guidelines for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Survey Operations (2006)	• Marine mammals	• 30 min. pre-survey observation period • Initiate soft-start with single airgun • Gradually add airguns over 20-45 min • Continuous visual observations required	• Shutdown zone varies from 200-1,500 m
United Kingdom	• Guidelines for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Surveys (2004)	• Seals, whales, dolphins, porpoises	• 30 min. pre-survey observation period • Initiate soft-start with smallest airgun • Gradually add airguns over 20-40 min	• 500 m shutdown zone

Table 5 Summary of Mitigation Measures for Seismic Operations in Key Countries (Modified from Tsoflias and Gill 2008)

Country	Regulation	Species Protected by the Regulations	Ramp up Restrictions	Shut down Requirements
United States-GOM	• Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program (2007)	• Marine Mammals and Sea Turtles	• 30 min. pre-survey observation period • Initiate soft-start with lowest energy-output/volume airgun • Gradually add airguns over 20-40 min • Continuous visual observations required	• 500 m shutdown zone

1.2.3 Drilling and Production Guidelines

The 2009 Draft Drilling and Production Guidelines include some of the prescribed regulatory compliance requirements with respect to safety, environmental protection and resource conservation but allow a “goal-oriented” approach for operators to implement and manage programs to comply with regulations and authorizations. These guidelines identify the engineering and safety standards to be followed in the design of offshore production facilities and contain the five following sections:

- Part I General Requirements: identifies the requirements for safety with respect to hazardous areas, emergency response, accident protection systems, safety systems and equipment and firefighting equipment.
- Part II Analysis and Design: establishes the standards to be followed for the engineering design, the design requirements, site-specific environmental criteria from the location and the design specifications for various types of platforms used in offshore developments.
- Part III Construction and Installation: specifies the engineering standards for fabrication and construction of various types of offshore structures and states requirements for the installation process.
- Part IV Operations and Maintenance: outlines requirements of operators to establish safe procedures for operations within the design parameters, maintain documents describing the design and load limitations of systems and equipment, monitor the platform, equipment and environmental conditions, maintain records and documents related to the operations and requires authorization before modification or alterations to structural equipment and systems and prepare periodic reports.
- Part V Records and Reporting: requires the operator to immediately report incidents involving loss of or threats to human life, loss of well control, spills of damage to equipment, and requires reporting of major activities to positioning a platform or conducting a heavy lift.

By law, operators are required to comply with the provisions of Parts IV and V. This document provides guidance to operators in Nova Scotia waters on the requirements for approval for the diverse components associated with offshore exploration and production programs and replaces the previous Drilling Regulations and Production and Conservation Regulations.

The detail and complexity of these standards precludes a detailed comparison with standards used in other jurisdictions; however, it should be noted that the standards followed in these guidelines draw on codes of practice, design and engineering specifications and best practices of internationally recognized regulatory authorities, professional organizations and standards identified in Canadian regulation pertaining to materials and engineering practices.

1.2.4 Offshore Chemical Selection Guidelines

The revised Offshore Chemical Selection Guidelines for Drilling & Production Activities on Frontier Lands (April 2009) reflect continued efforts to utilize less toxic substances in offshore drilling and production operations. These guidelines are revised at five-year intervals. Treatment chemicals may become part of discharges into the atmosphere or marine environment and therefore the selection of less toxic chemicals effectively reduces the environmental effects. The Guideline establishes selection criteria and procedures to be followed to identify the suitability of chemicals for use in offshore operations. The selection process draws on existing Canadian and International regulations and substances hazard listings including the following:

- *Pest Control Products Act*
- Domestic Substances List under the *Canadian Environmental Protection Act* (*CEPA*);
- New Substances Notification Procedure under *CEPA;*
- Toxic Substances listed under Schedule 1 of *CEPA;*
- Substances listed as *Pose Little or No Risk to the Environment* (PLONOR) under OSPAR;
- The Offshore Chemical Notification Scheme (OCNS) of the UK Centre for Environment, Fisheries and Aquaculture Science (CEFAS); and
- Chemical toxicity testing procedures which are approved by Environment Canada for use in this application.

The procedures used in offshore petroleum exploration and production programs identify substances in terms of their toxicity to the environmental and promote the use of the least toxic chemicals in offshore operations.

1.2.5 Petroleum Transportation

1.2.5.1 Pipelines

Pipelines are regulated under the *National Energy Board Act* where an NEB Certificate under a Section 52 or 58 Order is issued. The CNSOPB is also responsible for regulating petroleum activities offshore Nova Scotia. In 2008, the NEB and the CNSOPB signed a memorandum of understanding to increase the efficiency and effectiveness of pipeline regulations. As construction, operation, decommissioning, abandonment and removal of offshore pipelines is within the jurisdiction of both agencies, the new agreement reduces regulatory overlap by setting criteria for areas where cooperation can occur like data sharing, emergency management, monitoring and enforcement.

Marine pipeline infrastructure can be a concern for commercial fishing license holders due to the possibility of causing damage to gear. Operators also consider the effect of fishing gear on subsea pipelines. In 2006, Det Norske Veritas issued DNV-RP-F111 as an update to DNV Guidelines No.13 "Interference between trawl gear and pipelines" issued in 1997. This Recommended Practice provides criteria and guidance on design methods for pipelines subjected to interference from trawling gear (DNV 2007).

1.2.5.2 Tankers

Shipping is an important method of transporting petroleum hydrocarbons and is under the jurisdiction of Transport Canada. The *Canada Shipping Act, 2001* and MARPOL are key elements which regulate shipping in Canadian waters. The *Canada Shipping Act, 2001* is the principal legislation governing safety in marine transportation and protection of the marine environment. The main difference between the *Canada Shipping Act* previous to the updated *Canada Shipping Act, 2001* enacted in 2007 is a less prescriptive and more performance-based approach.

MARPOL is an international convention whose aim is the prevention of pollution of the marine environment by ships from operational or accidental events. Important technological advances to protect the marine environment from spills have occurred in shipping including the phase out of single-hulled tankers. International requirements for double-hulled oil tankers were introduced in 1993 through an amendment to Annex I of MARPOL. Amendments to MARPOL were adopted in 2001 and became effective in 2002. These amendments accelerate the phase-out schedule for large single-hulled tankers beginning in 2003 with final phase out occurring in 2015. There are however some provisions, for allowing existing tankers to continue to operate (*i.e.,* with existing tankers that meet the side protection requirements in the International Bulk Chemical Code for type 2 cargo tank locations and the bottom protection specified in the regulation 13E(4)(b) of Annex I of MARPOL).