NLHFRP

Newfoundland & Labrador
Hydraulic Fracturing
Review Panel

Unconventional Opportunities & Challenges

Results of the Public Review of the Implications of Hydraulic Fracturing Operations in Western Newfoundland

Final Report

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LIST OF ABBREVIATIONS & ACRONYMS

3-D: Three dimensional
AER: Alberta Energy Regulator
ALARP: As Low as Reasonably Practicable
AIS: Anomalous Induced Seismicity
AM: Adaptive Management
BCOGC: British Columbia Oil and Gas Commission
BBL (bbl): Barrel
bopd: Barrels of Oil per Day
CWN: Canadian Water Network
CapEx: Capital Expenditure
CAPP: Canadian Association of Petroleum Producers
CBC: Canadian Broadcasting Corporation
CCA: Council of Canadian Academies
C-CORE: An applied research and development corporation of Memorial University
CCS: Carbon Capture and Storage
cm: Centimetres
C-NLOPB: Canada-Newfoundland and Labrador Offshore Petroleum Board
C-NSOPB: Canada-Nova Scotia Offshore Petroleum Board
CNSN: Canadian National Seismograph Network
COMEST: UNESCO World Commission on the Ethics of Scientific Knowledge and Technology
COP21: 2015 Paris Climate Change Conference
DNR: Department of Natural Resources
EL: Exploration Licence
FES-NL: Fire and Emergency Services – Newfoundland and Labrador
FPIC: Free, Prior, and Informed Consent
GDP: Gross Domestic Product
GHG: Greenhouse Gas
HAPs: Hazardous Air Pollutants
HF: Hydraulic Fracturing
HIA: Health Impact Assessment
IPIECA: The global oil and gas industry association for environmental and social issues
IPCC: Intergovernmental Panel on Climate Change
km: Kilometers
km^2: Square Kilometres
m: Metres
m^3: Cubic Metres
MCOR: Marcellus Center for Outreach and Research
MM: Million
MW: Megawatt
M_L: Local Magnitude
NEB: National Energy Board
NL: Newfoundland and Labrador
NPV: Net Present Value
NLHFRP: Newfoundland and Labrador Hydraulic Fracturing Review Panel
NSERC: Natural Sciences and Engineering Research Council of Canada
O&G: Oil and Gas
OCCEE: Office of Climate Change and Energy Efficiency
OpEx: Operating Expenditure
OWA: Orphan Well Association
PEEP: Petroleum Exploration and Enhancement Program
PM: Particulate Matter
PP: Precautionary Principle
PSAC: Petroleum Services Association of Canada
REC: Reduced Emissions Completion
REDB: Regional Economic Development Board
scf: Standard Cubic Feet
SEP: Strategic Economic Plan
SLO: Social Licence to Operate
TLP: Traffic Light Protocol
UK: United Kingdom
UNESCO: United Nations Educational, Scientific and Cultural Organization
US (USA): United States (of America)
USGS: United States Geological Survey
VOBB: Voice of Bonne Bay
VOC: Volatile Organic Compound

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1 PANEL MANDATE AND REPORT STRUCTURE

1.1 Mandate

This report reflects the views of the independent volunteer Review Panel (hereafter referred to as the "Panel") that was constituted by the Government of Newfoundland and Labrador (hereafter referred to as the "Government") under Terms of Reference (NLDNR, 2014) that included the following mandate:

> *"The mandate of the Panel is to conduct a public review and advise the Minister of Natural Resources on the socio-economic and environmental implications of the hydraulic fracturing process with respect to possible exploration and development of the petroleum resources of Western Newfoundland."*

Figure 1 shows the region of Western Newfoundland that was considered by the Panel during the course of its work.

Adhering to the Terms of Reference and utilizing information made available to the Panel through written submissions and studies commissioned, undertaken, or reviewed by the Panel, this report provides advice and recommendations to the Minister of Natural Resources, Government of Newfoundland and Labrador (hereafter referred to as the "Minister"). It is the intent of the Panel that this report presents the Panel's work and associated recommendations in a format that is both accessible to and comprehensible by the citizens of Newfoundland and Labrador.

To facilitate an understanding of the technical terms used in this report, hyperlinks (i.e. underlined words) are included in the electronic version of the report to definitions in the Schlumberger Oilfield Glossary (www.glossary.oilfield.slb.com) for specific terms that are used in the oil and gas industry (Schlumberger, 2016a).

The Panel developed this report with the objective of both advising the Minister, as per the Terms of Reference, as well as raising the public understanding of hydraulic fracturing within the context of potential development in Western Newfoundland. For this reason, the main body of the Panel's report includes considerable background information about hydraulic fracturing techniques and full-scale operations.

1.2 Panel's Focus on the Green Point Shale

In the context of considering unconventional oil and gas development in Western Newfoundland, the Panel chose to focus on the Green Point shale formation, which is of current interest for commercial development. An extensive discussion of the Green Point shale is found in a report entitled "The Green Point Shale of Western Newfoundland" (Hinchey, et al., 2014), a report by provincial government scientists working for the Department of Natural Resources (DNR). For the purpose of the Panel's report, the report of the DNR scientists will be referred to as the "Green Point Report". The location of the prospective area of the Green Point formation is illustrated in Figure 2.

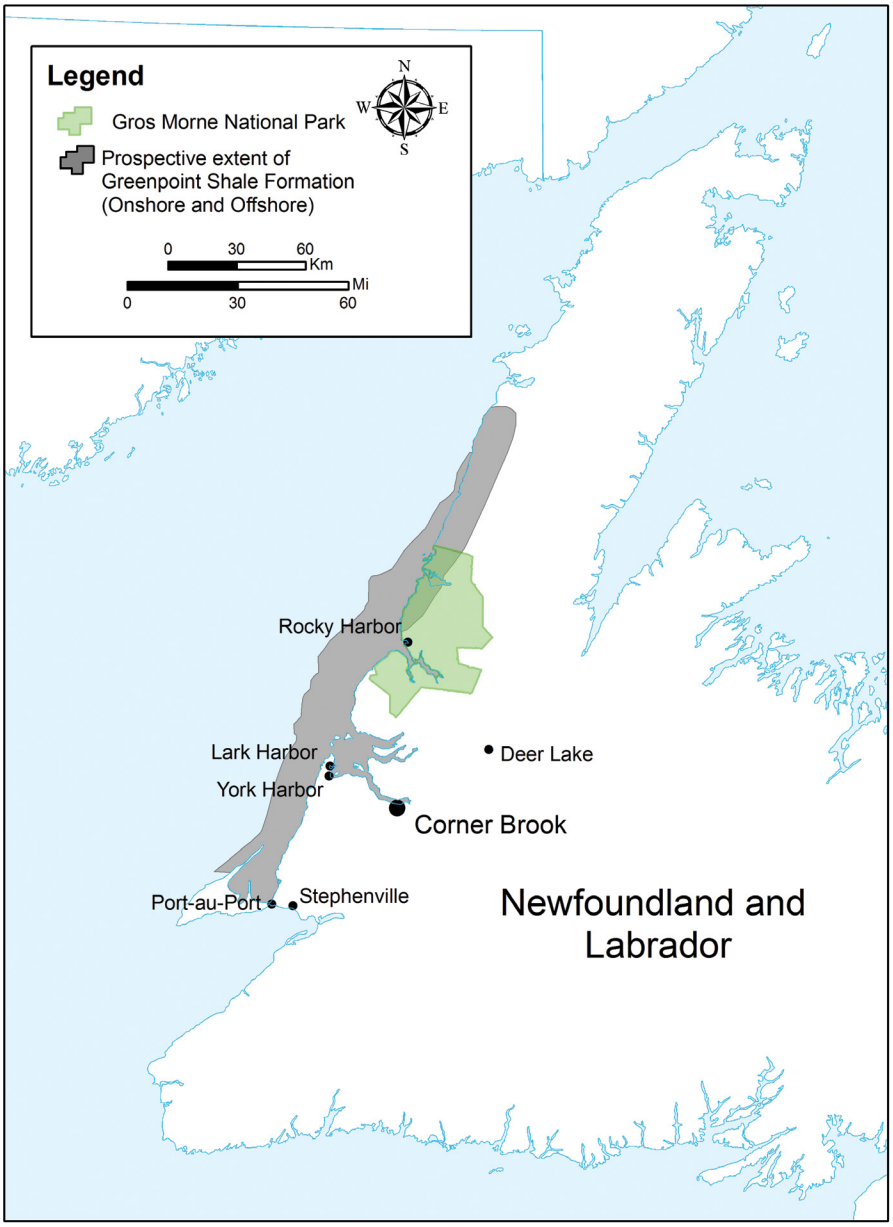
Shoal Point Energy's website (Shoal, 2013) provides a proponent's perspective on the commercial opportunity associated with development of the Green Point shale resource. Shoal Point Energy holds an exploration licence for the offshore area around Port au Port Bay. In this report, the term "proponent" refers to a company participating, or intending on participating, in unconventional oil and gas development.

In addition to the Green Point shale, previous exploration in Western Newfoundland identified the existence of some other tight formations that might benefit from the application of hydraulic fracturing (Hinchey, et al., 2014). The Panel did not receive any specific input through the review process suggesting these other formations be developed using hydraulic fracturing. These other formations are considered to be *"secondary unconventional targets"* compared to the *"major unconventional exploration targets"* in the Green Point shale formation (Burden, 2016). Given the immediate interest in the Green Point shale as a potentially significant target for unconventional oil and gas development, the Panel selected the Green Point shale resource as a basis for exploring the specific issues in its mandate.

Figure 1. Google Maps image of area of Western Newfoundland considered by Panel.

1.3 Report Structure: A Reader's Guide

The purpose of this report is twofold. First, it both constitutes the Panel's advice to the Minister with respect to hydraulic fracturing in Western Newfoundland and provides details that support this advice. Second, the report attempts to respond to information gaps that the Panel identified in its review process with respect to balanced sources of public information about hydraulic fracturing in the context of Western Newfoundland. In this respect, the Panel hopes that this report will have more general, public use beyond providing advice to the Minister.



Data Sources: MorningStar N51-101 Compliant Report prepared for Shoal Point Energy and mapping prepared by Dept of Natural Resources which included the results of well evaluation conducted on Long Point M-16 and Shoal Point K-39 on the Port-au-Port Peninsula and well evaluation conducted on Seamus #1 and Finnegan #1 in the Parson's Pond area.

Figure 2. Location of the Green Point shale in Western Newfoundland (provided by Department of Natural Resources).

Section 2 of the report provides a brief definition of hydraulic fracturing, as well as an overview of the terminology normally used when discussing hydraulic fracturing. Section 3 summarizes the Panel's primary task, as set out in its Terms of Reference, while Section 4 describes the public review process implemented by the Panel. Hydraulic fracturing operations are explained in more detail in Section 5. Sections 6 and 7 review the policy, economic development, and community contexts for hydraulic fracturing operations in Western Newfoundland. With a particular focus on the geology of the Green Point shale, Section 8 considers the Western Newfoundland geological context. To help illustrate the scale of a potential industrial development and the associated potential costs and benefits, the Panel developed a full-scale development scenario for the Green Point shale resource as discussed in Section 9. Section 10 reviews the results of the public opinion survey commissioned by the Panel, analyzes the public

submissions received by the Panel, and identifies the primary issues of public concern expressed in the submissions. The concepts of safety, risk, and risk management are discussed in Section 11, along with the risks associated with a loss of well integrity. Section 11 also includes a review of the primary public health, environmental, and socio-economic issues that give rise to potential risks. This is followed, in Section 12, by a discussion of community engagement, with specific reference to the issue of a social licence to operate. Section 13 presents the Panel's primary recommendation, while Section 14 offers a series of supplementary recommendations pertaining to public policy, planning and science considerations; socio-economic considerations; environmental considerations; public health considerations; regulatory considerations; and other scientific and technical considerations. Finally, Section 15 provides the Panel's concluding comments. As well, reports from subject-matter experts were commissioned by the Panel, and these are provided in the appendices to this report. These appendices, which include detailed, technical discussions on topics relevant to the Panel's work, reflect the perspectives of the authors in response to specific subject-matter requests from the Panel.

Other Canadian panels or groups have undertaken considerable recent work on matters that overlap the Panel's mandate. These include the Council of Canadian Academies Expert Panel on Harnessing Science and Technology to Understand the Environmental Impacts of Shale Gas Extraction (CCA, 2014), the Nova Scotia Independent Review Panel on Hydraulic Fracturing (NSIRPHF, 2014), the New Brunswick Commission on Hydraulic Fracturing (NBCHF, 2016), and the Water and Hydraulic Fracturing Program of the Canadian Water Network (CWN, 2015a). These reports give detailed consideration and background information to important public health and environmental issues relevant to the work of the Panel. Rather than repeating the results, analysis, discussions, and recommendations of the other reports, the Panel utilized the reports as important and relevant background information in completing its own work. Moreover, the reports serve as a basis for some of the Panel's recommendations, and the reader is encouraged to review the other reports.

To date, consideration of hydraulic fracturing in other Canadian reports has primarily dealt with shale gas development. This is different from the Western Newfoundland context, at least initially. Specifically, the Western Newfoundland resource of particular interest is the Green Point shale, an oil resource. Even so, many of the issues are similar to those of a shale gas development.

2 HYDRAULIC FRACTURING TERMINOLOGY

2.1 Conventional versus Unconventional Oil and Gas

Figure 3 (Rodgers, 2015) illustrates the difference between conventional and unconventional oil and gas operations. For conventional oil production, wells are drilled into a reservoir containing a combination of oil, gas, and water, and these fluids flow or are pumped to the surface through a conventional oil and gas well.

A conventional oil and gas reservoir is comprised of porous and permeable rocks, known as "reservoir rocks". The porous rock provides space for the oil and gas to accumulate, while permeability allows the oil and gas to flow easily. Oil and gas are formed in "source rocks" that are rich in organic matter and are subjected to the right temperatures and pressures over a long period of time. As the source rock matures, the oil and gas migrate from the source rocks into the reservoir rocks. The resulting accumulation of oil and gas in the reservoir rocks, as illustrated by the well on the left hand side of Figure 3, is the target for oil and gas production from a conventional oil and gas well.

In the case of unconventional oil and gas resources associated with some shale rock formations, such as the Green Point formation in Western Newfoundland, the shale source rock has very low permeability. The oil and gas formed in the low permeability source rock does not flow into reservoir rocks. Instead, it remains trapped within the shale source rock. In order to develop the oil and gas resources that are trapped within the shale source rock, it is necessary to increase the permeability of this rock to allow the oil and gas to flow into an unconventional oil and gas well. This is illustrated by the well on the right-hand side of Figure 3.

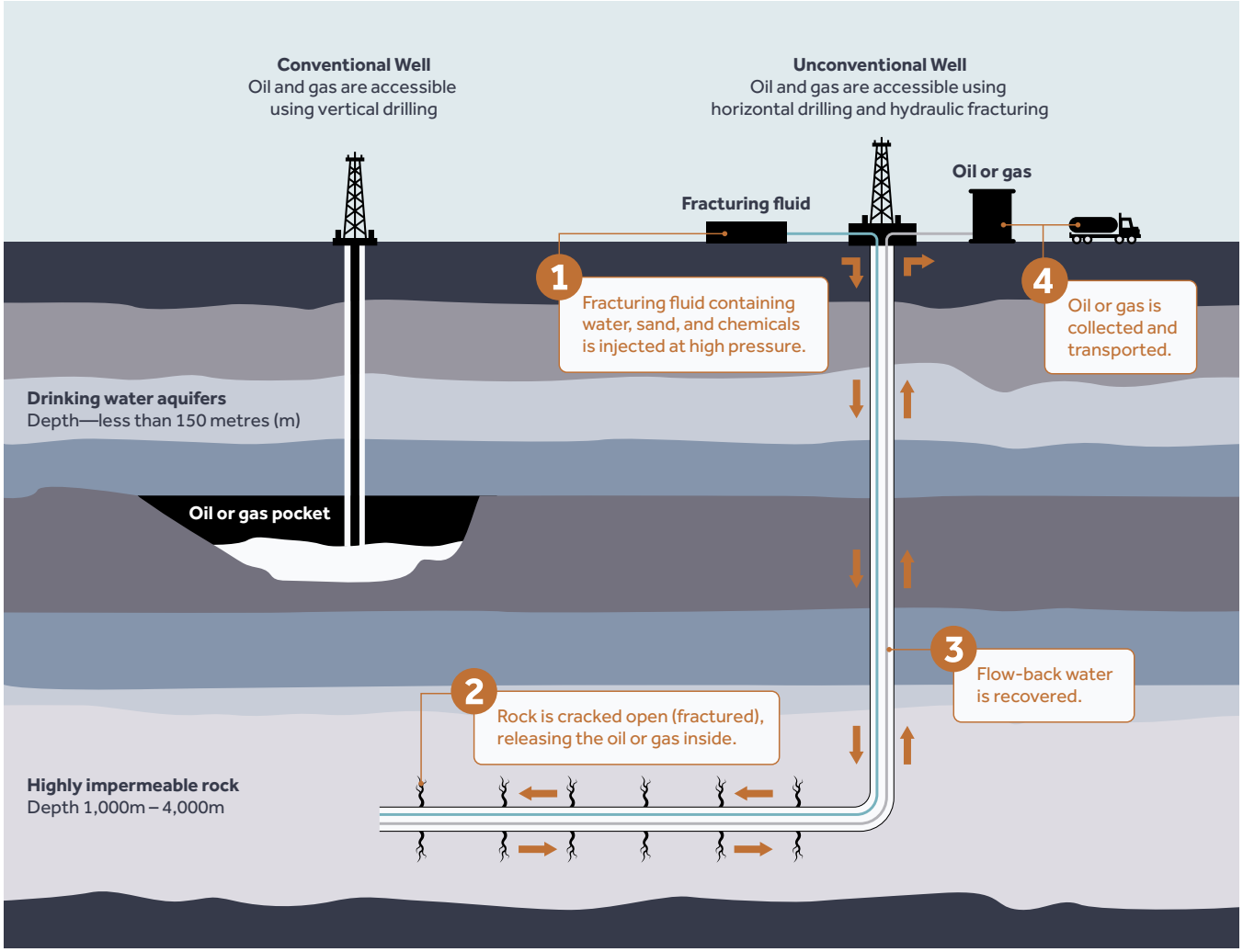


Figure 3. Illustration of conventional and unconventional oil and gas operations, (adapted from Rodgers, 2015).

Hydraulic fracturing is the process of injecting hydraulic fracturing fluid into shale source rock at a pressure that exceeds the formation fracture pressure. This will fracture the low permeability source rock near the horizontal section of the wellbore and increase the permeability in the immediate vicinity of the wellbore. Specifically, hydraulic fracturing opens existing pathways through the shale. It also creates new pathways. The fractured shale source rock is sometimes referred to as the "shale reservoir".

In the past, the term shale oil referred exclusively to oil extracted from oil shale, organic-rich fine-grained rocks that are viewed as precursors to conventional oil generation. The organic material is semi-solid, and the large molecules are usually heated to a liquid called "shale oil", consisting of smaller molecules that can be refined to make useful products.

The term "shale oil" has taken on a new meaning in the last 10 years. In the context of recent oil and gas development, the term "shale oil" is now applied to oil found in source rocks that would be targets for hydraulic fracturing. In the new terminology, the Green Point shale is a "shale oil play", although there may also be large volumes of natural gas dissolved in the oil that will be produced. This report uses the term "shale oil" to mean this more modern usage. Shoal Point Energy uses the term "oil-in-shale" to distinguish the modern usage of the term "shale oil" from its earlier usage (Shoal, 2013).

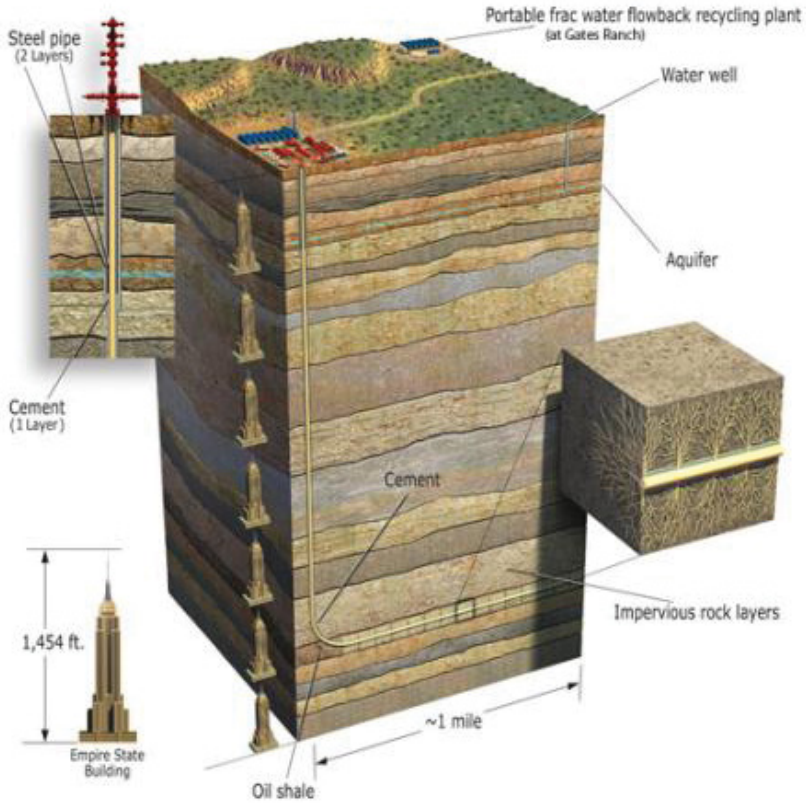


Figure 4. Illustration of vertical extent of an unconventional oil and gas well (Fracfocus, 2016).

The increase in permeability of the fractured shale near the wellbore allows shale oil and shale gas to flow into the wellbore. As a result, the productivity of wells may be increased, which results in commercially viable production. Since the oil and gas recovered from a hydraulically fractured well is limited to the oil and gas near the wellbore, the number of wells required for economic development of a resource is typically much larger for unconventional oil and gas development than for conventional oil and gas development.

Figure 4 (Fracfocus, 2016) illustrates the horizontal section of the well, which is located in the subsurface layer that would be fractured. The fracture occurs deep below the surface, separated from any ground or surface water sources by layers of impermeable rock. The shales of commercial interest in Western Newfoundland are expected to be 1.0-3.5 km below the surface.

In addition to using hydraulic fracturing to increase the permeability of shale source rock, hydraulic fracturing may also be used to increase the permeability of other tight oil reservoirs that are sometimes associated with sandstones and carbonate rocks (Precht & Dempster, 2014a).

There are a couple of key differences between the scenario illustrated in Figure 3 and a Green Point shale development scenario. First, as noted in the Green Point Report (Hinchey, et al., 2014) and as discussed in more detail in Section 8 of this report, the subsurface geology of the Green Point formation is not the simple layered sequence illustrated in Figure 4 and common for unconventional oil and gas developments in other jurisdictions. The second significant difference is that unconventional oil and gas development of the southern part of the Green Point shale would, as illustrated by Figure 2, require use of onshore-to-offshore wells, with wellheads located onshore and the horizontal part of the wells extending out under the seabed rather than under land as illustrated in Figure 3. This is discussed in more detail in Section 9.

2.2 Well Stimulation Using Hydraulic Fracturing

In general, well stimulation refers to processes that improve, or stimulate, the production rate from water, oil, and gas wells. For example, hydraulic fracturing is a common technique to stimulate domestic water wells in granites and other low permeability rocks by opening pathways to increase the flow of water into the well. In an oil and gas context, as illustrated in Figure 3, hydraulic fracturing is a process of pumping a fracturing fluid into the shale through a wellbore in order to fracture the shale close to the wellbore (i.e., within 150 m) so that oil and gas can flow from the fractured shale into the wellbore.

Figure 5 illustrates the constituents of hydraulic fracturing fluid, which is a mixture of make-up water (typically fresh water), chemicals, and proppant (typically sand). The hydraulic fracturing fluid is pumped into the shale at high pressure in order to open up existing or new fractures. Under this pressure, the proppant is forced into the fractures to wedge, or prop open, the fractured shale once the pressure is dropped. This fractured shale has an increased permeability which allows oil and gas to flow more easily into the wellbore. This well stimulation technique is sometimes referred to as a "frac job" (i.e., to fracture a well) or "fracking". Once the well is stimulated and is put into production, a pump may be placed in the well to lift the fluids (i.e., oil, gas, and water) up the wellbore. These fluids are collected at the wellhead on the surface and separated into their components. If a well only produces dry gas (i.e., no associated liquids), a pump is not required.

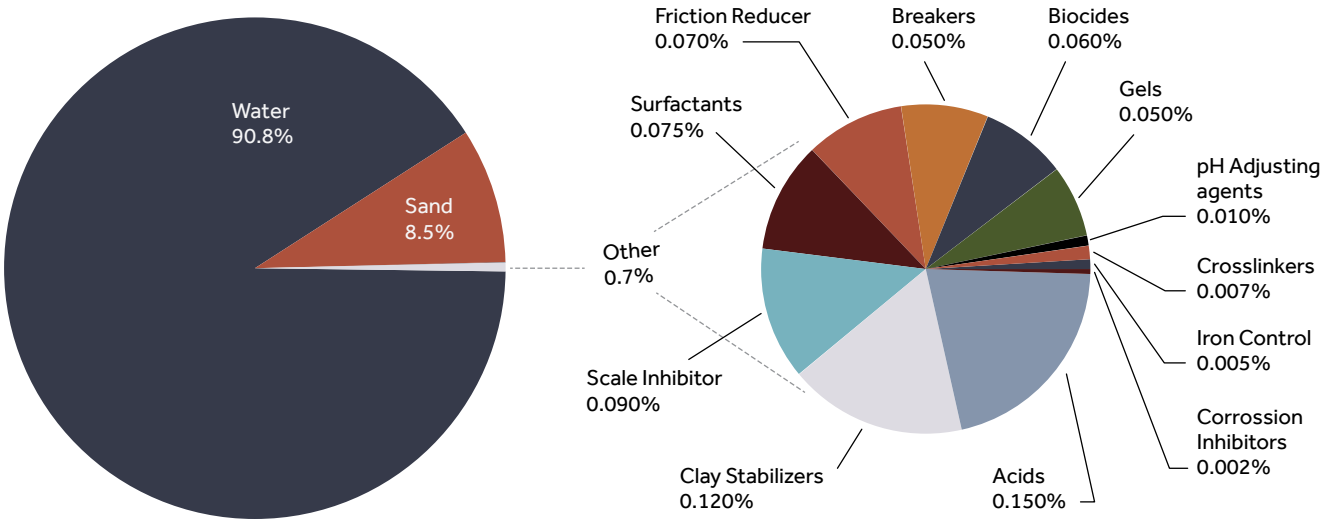


Figure 5. Chemical constituents of a hydraulic fracturing fluid (Ferrer & Thurman, 2015).

The purpose of chemicals used in hydraulic fracturing depends on the nature of the rock and the stimulation goal. If the goal is to open fairly-wide cracks which are close to the wellbore and to keep these cracks open, then the fracturing fluid may be formulated to have high viscosity. This will enable the fluid to carry the proppant more easily. High viscosity is achieved using various non-toxic gums, such as guar gum or xanthan gum. Small amounts of other chemicals are added to prevent the fluid from fermenting and to help reduce the viscosity once pumping stops. Some chemicals used in hydraulic fracturing have biological toxicities, and the extent of the hazard that they present depends on how concentrated they are when, or if, an adverse event, such as a spill, occurs.

2.3 Use of the Terms Hydraulic Fracturing, Hydraulic Fracturing Operations and Unconventional Oil and Gas Operations in This Report

In the oil and gas industry, the term "hydraulic fracturing" refers exclusively to well stimulation and does not include exploration, drilling, production, and other activities. In this report, the term "hydraulic fracturing operations" is used to describe the "all-inclusive industrial process" that includes:

- exploration activities, such as seismic and magnetic surveys, and the drilling of exploratory wells;
- development of infrastructure, including access roads, pipeline rights-of-way, and drill pads;
- construction of transportation and storage facilities, such as pipelines and storage tanks at ports;
- drilling and construction of production wells;
- well completion and stimulation using hydraulic fracturing technology, including the supply of make-up water and disposal of wastewater following fracturing;
- production activities, including disposal of water that is produced with the oil and gas;
- re-stimulation of wells;
- well decommissioning and abandonment; and
- site restoration.

In addition, in this report, the term "unconventional oil and gas development" also refers to this all-inclusive industrial process. Hydraulic fracturing operations are described in detail in various other reports (Precht & Dempster, 2014a) (CCA, 2014) (NSIRPHF, 2014) (NBCHF, 2016). They are also discussed in Section 5 and Appendix D (Dusseault, 2016) of this report.

3 WORK OF THE REVIEW PANEL

The primary task for the Panel, as outlined in the Terms of Reference, was to make a recommendation on *"whether or not hydraulic fracturing should be undertaken in Western Newfoundland"* (NLDNR, 2014). Based on the scope of activity outlined in the Terms of Reference, the Panel interpreted the use of the term "hydraulic fracturing" in the Terms of Reference to mean the "all-inclusive industrial process" described in Section 2.3.

To fully appreciate the Panel's report, it is important to understand the situation in Newfoundland and Labrador as it pertained to approvals of applications for hydraulic fracturing at the time the Panel was constituted. Specifically, as noted in the Panel's Terms of Reference:

> *"In November 2013, the Minister of Natural Resources announced that no applications for onshore and onshore-to-offshore petroleum exploration using hydraulic fracturing would be accepted until government could undertake a balanced review of regulations, rules, and guidelines in other jurisdictions; complete the technical work necessary to fully assess the geological impact in Western Newfoundland; and following this process, undertake public consultations to ensure that residents can comment and are fully informed before any decisions relating to hydraulic fracturing are made"* (NLDNR, 2014).

Although formal moratoria have been legislated in Nova Scotia and New Brunswick, the "pause" in accepting applications involving hydraulic fracturing in Western Newfoundland is not a formal moratorium, despite sometimes being described as such by members of the public. Rather, the "pause" was an operational decision of the province's Department of Natural Resources.

As a basis for making a recommendation to the Minister, the Panel reviewed a substantial body of information gathered during the review process including:

- all documents provided to the Panel by Government upon the appointment of the Panel;
- all documents provided to the Panel by Government at the request of the Panel;
- all documents sourced by individual members of the Panel;
- expert reports on specific topics that were commissioned by the Panel or prepared by individual members of the Panel; and
- over 600 documents that were received in response to a request by the Panel for submissions from the general public and stakeholder groups, including documents that were received following individual and group meetings, public consultation sessions, and several visits to Western Newfoundland by the Panel during the course of its work.

4 OVERVIEW OF THE PUBLIC REVIEW PROCESS

The independent Panel was appointed by the Minister in October 2014 to conduct a public review of the socio-economic and environmental implications of hydraulic fracturing in Western Newfoundland. The biographies of the members of the Panel are included in Appendix A.

The Panel was also tasked with making a recommendation to the Minister on whether hydraulic fracturing operations should be undertaken in Western Newfoundland. Following consultation with both the provincial Department of Environment and Conservation and the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), the Minister issued the Terms of Reference for the Panel along with research completed during the Government's internal review of hydraulic fracturing (NLDNR, 2014).

4.1 Website

In April 2015, a website (www.nlhfrp.ca) was launched to provide an opportunity for the sharing of information between individual members of the public, other stakeholder groups, and the Panel. The website served as an effective interface that allowed the public and interested groups to make submissions to the Panel, to request to meet with or make a presentation to the Panel, and to review all documents considered by the Panel.

4.2 Information Gathering

The Panel gathered information relevant to its mandate through two approaches: (1) direct sourcing and commissioning of documents and reports, and (2) accepting submissions from individuals, groups, and organizations wishing to provide input to the Panel.

Following a 45-day period (i.e., April 15 - June 1, 2015) for submission of information to the Panel, the Panel was available for meetings with those who requested to meet face-to-face or via teleconference in order to provide a brief review of their written submission. The Panel also sought clarification of information contained in some submissions when the message being conveyed was not clear to the Panel.

All submissions and other documents were added to the website as received to ensure transparency and openness. Regular updates alerted the public to the documents under consideration by the Panel. All forms of input were welcomed, including detailed written submissions addressing one or more topics within the Panel's mandate, form letters, poems, stories, works of visual art, and songs. Submissions from over 550 individuals and groups were received, and the website remained open to receive submissions until May 16, 2016.

4.3 Public Consultations Sessions and Meetings with the Panel

The process for public consultation evolved with the number of submissions received. The original call for submissions specified that the Panel would hold public consultation sessions in Stephenville and Corner Brook after July 15, 2015, to accommodate requests to make presentations to the Panel. Priority for individual or group meetings with the Panel or public presentations to the Panel was to be allocated to those individuals or groups who, by June 1, 2015, had requested to present, or discuss, a summary of the salient features of their written submissions to the Panel.

Based on the number and nature of the requests received by June 1, 2015, the Panel decided to hold four, rather than two, public consultation sessions from October 13-16, 2015. These public consultation sessions were scheduled to take place in Corner Brook, Stephenville, Rocky Harbour, and Port au Port East. The dates, times, and locations of these public consultation sessions were announced on the Panel's website and advertised in relevant media prior to September 1, 2015. As well, prior to September 1, 2015, revised details about the sessions and meetings were provided to the individuals and groups who had requested to present or meet with the Panel.

The Panel announced the public consultation sessions through advertisements placed in the Western Star newspaper and on CBC and Voice of Bonne Bay (VOBB) radio stations, as well as through notifications sent to all municipalities in the region. In addition, the Gros Morne Cooperating Association, the Port au Port/Bay St. George Fracking Awareness Group, and the Western Environment Centre also promoted the consultation process, including opportunities to participate in the public consultation sessions.

Besides the four public consultation sessions, which saw 80 individuals and groups present to the Panel, the Panel also held 15 meetings with individuals and groups that requested face-to-face or teleconference meetings with the Panel. It is estimated that approximately 600 people attended the public consultation sessions in October 2015.

4.4 Public Opinion Survey

The Panel commissioned an independent survey to gauge public opinion about a range of issues related to unconventional oil and gas development in Western Newfoundland. Complete details regarding the survey are provided in Appendix O (MQO, 2015) of this report. In addition, the Panel commissioned an independent analysis of the public opinion survey results, which is included as Appendix P (Martínez-Espiñeira, 2016). A discussion of the public opinion survey is included in Section 10 of this report.

4.5 Supplementary and Commissioned Reports

Members of the Panel prepared supplementary reports on a number of topics within the scope of the Panel's work. These supplementary reports, which are included as appendices to this report, include:

- review of hydraulic fracturing operations and wellbore integrity in a Western Newfoundland context: Appendix D (Dusseault, 2016);
- review of economic and employment data from the Community Accounts dataset for Western Newfoundland: Appendix E (Locke, 2016);
- review of potential effects on human health: Appendix F (Keough, 2016); and
- review of water resources in Western Newfoundland: Appendix H (Gagnon & Anderson, 2015).

Where the Panel felt that there were knowledge gaps concerning key topics under consideration by the Panel, or where the Panel felt that independent input on a particular topic would be helpful to its work, the Panel commissioned or retained "subject-matter experts" to prepare reports containing background information and advice related to their areas of expertise. In particular, the Panel commissioned reports in the following topic areas:

- review of the relationship among income, wealth, and health: Appendix G (May & May, 2015);
- review of air and land impacts, waste management, and site restoration: Appendix I (Husain, et al., 2016);
- review of geological risks: Appendix J (Burden, 2016);
- review of induced seismicity risks: Appendix K (Eaton & Krebes, 2016);
- review of approaches to risk assessment and management: Appendix L (Khan, 2016);
- review of regulatory issues: Appendix M (Lahey, 2016);
- analysis of the written public submissions: Appendix N (Storey, 2015);
- analysis of the public opinion survey results: Appendix P (Martínez-Espiñeira, 2016);
- analysis of potential project economics and fiscal impact: Appendix Q (Rodgers, 2015); and
- analysis of potential employment and Gross Domestic Product (GDP) impacts: Appendix R (EcoTec, 2016).

Biographies for the subject-matter experts who prepared the commissioned reports are found in Appendix B.

The supplementary and commissioned reports, which are included in their entirety in the appendices to the Panel's report, reflect the expert opinions of the authors. These documents served as important background information for the Panel's work and for the Panel's final report. Readers are encouraged to review these appendices.

4.6 Panel Visits to Western Newfoundland

Members of the Panel made four visits to Western Newfoundland during the course of its work, including four days of meetings and public consultation sessions in Western Newfoundland in October 2015. In June 2015, the Panel held a meeting in Corner Brook that included a field trip to the Port au Port Peninsula. At the same time, R. Gosine visited the York Harbour and Lark Harbour area. In August 2015, three members of the Panel (R. Gosine, W. Locke, and K. Keough) visited Gros Morne National Park and the surrounding area and received, from the Gros Morne Cooperating Association, an orientation to Gros Morne National Park and the enclave communities. In August 2015, R. Gosine, W. Locke, and K. Keough visited Lark Harbour and York Harbour, with an orientation to the region by I. Simpson, S. Simpson, and S. Jansen. During this trip, R. Gosine, W. Locke, and K. Keough also visited the Port au Port Bay area, with an orientation to the region by the Port au Port/Bay St. George Fracking Awareness Group.

4.7 Visit to the Marcellus Center at Penn State University

In September 2015, R. Gosine, G. Gagnon, and K. Keough visited the Marcellus Center for Outreach and Research (MCOR) at Penn State University (www.marcellus.psu.edu). MCOR's mission is to pursue science-based research and to develop an understanding of the many issues surrounding the development of shale energy in Pennsylvania and around the world.

The visit to MCOR included an orientation to the area around Williamsport, Pennsylvania, where there is a well-established shale gas industry. This orientation involved tours of facilities used during hydraulic fracturing operations, including a well undergoing stimulation, several producing wells, a proppant-storage facility, a water-treatment facility, a water-handling facility, water and gas pipelines, and a solid-waste-handling operation. The visit also entailed significant driving on the roadways around Williamsport thereby allowing the members of the Panel to observe truck traffic involved in the transportation of proppant, fracturing fluids, and water. Meetings were arranged with local government officials, environmental regulators, and a lawyer who represents landowners in negotiations with oil and gas companies. In addition, the Panel had opportunities to speak informally with individuals living and working in areas where shale gas activities are taking place.

4.8 The Panel's Approach to Its Work

While the questions posed in the Terms of Reference (NLDNR, 2014) provided a useful starting point for its work, the Panel was not restricted to just these questions. The information-gathering phase of the Panel's work provided a sharper focus on the issues of most significance to addressing the primary task of advising the Minister. Consequently, the work of the Panel concentrated on the issues most relevant to the health and well-being of the people of, and environment within, Western Newfoundland.

Through the review process, the Panel considered over 800 documents, including over 600 written submissions. The Panel was further informed through the public consultation sessions, face-to-face meetings, and teleconference meetings with a number of individuals and groups. In addition, the Panel's assessment took into account the work of experts who were commissioned to provide reports on specific topic areas outlined in the Terms of Reference (NLDNR, 2014). The analysis and recommendations presented in this report follow from careful consideration of the information gathered throughout the entire consultation process.

This report represents general agreement among all members of the Panel with respect to the background information presented in this report, the primary recommendation of the Panel presented in Section 13, and the additional supplementary recommendations presented in Section 14.

A final draft of this report was independently reviewed by individuals that the Panel felt would be able to offer valuable perspectives and insights to the Panel as it completed its work. The biographies of the individuals who provided these reviews are included in Appendix C.

5 OVERVIEW OF HYDRAULIC FRACTURING OPERATIONS

Decades ago it was observed that production rates from wells in deep, low-permeability rocks (e.g., shale, fine-grained silts) could be low and uneconomical. Typically, low production rates arise naturally when sediments are fine-grained or contain significant quantities of clay minerals, or when the rocks themselves have very low permeability (i.e. ability for fluid to move through a material). Often, the natural fractures in these low permeability rocks are held closed by high stresses in the earth. In the past, low production rates may have been made worse by poor drilling methods that partially blocked the natural pores and fractures in the rock near the wellbore. To improve the production rate of such wells, stimulation processes were developed. One of the earliest was "shooting a well", which involved dropping a container of raw nitroglycerine down a wellbore so that it exploded adjacent to the target rocks, opening up cracks in the rock mass, and greatly improving the ability for fluid to flow into the region near the wellbore.

Today, modern well construction includes well-site planning and preparation, drilling, casing and cementing, completion and stimulation, and site maintenance (CSUR, 2015). Stimulation methods that are safer and more effective than "shooting a well" have been practiced for many decades and continue to evolve. For example, acid stimulation involves injecting concentrated acid to dissolve clay blockages and etch natural fractures in rocks near the wellbore. Solvent treatment involves placing a solvent into the near-wellbore region to dissolve tarry deposits that block the pores and inhibit fluid flow. Many stimulation agents are highly toxic and hazardous in their pure and transported form, and must be handled in accordance with safety and public health regulations.

Well stimulation using hydraulic fracturing, first carried out in the late 1940s in the USA and as early as 1952-1953 in Manitoba and Alberta, rapidly replaced "well shooting". In its simplest form, which is widely used to stimulate domestic water supply wells, pumps are used to increase the fluid pressure within an isolated section of a well until it is high enough to open existing fractures, or to create new fractures. Usually, the proppant is a rounded quartz sand that is added to the injected water to hold open the fractures once pumping ceases and the fluid pressures decline relative to the high stresses at depth.

In a low-permeability oil and gas reservoir, such as the Green Point shale in Western Newfoundland, the hydraulic fracturing process opens natural fractures in a region that can extend as much as 100 m out from the wellbore in a particular orientation. The orientation of the induced fractures depends on the orientation of the natural stress fields in the earth. This is important information to use in selecting the direction in which to drill the wells and in designing an effective hydraulic fracturing treatment.

Today, most hydraulic fracturing is carried out in wells that are drilled in a horizontal orientation using directional drilling technology to maximize well productivity. This is because the geological strata (i.e., rock layers) that contain the resource are relatively thin, typically less than 150 m in thickness. As illustrated in Figure 3 in Section 2.1, during the drilling of unconventional oil and gas wells, once the deep oil and gas bearing shale has been reached by a vertical well section, the well is turned and extended horizontally. Typical horizontal well lengths are in the order of 2-3 km, although longer horizontal wells are possible. A horizontal well is much more productive than a vertical well that might only pass through a few tens of metres of a reservoir of interest. A long horizontal well drains a larger volume of the reservoir, and many horizontal wells can be installed from one drilling site.

5.1 Well Pad Development

The process of developing the well pads for a commercial-scale development is a major construction project spread out across many sites. This *"includes the construction of roads for the transport of heavy equipment such as the drill rig, leveling of the site, structures for erosion control, the excavation of pits to hold drilling fluids and drill cuttings, and the placement of racks to hold the drill pipe and casing strings"* (Fracfocus, 2016). During well pad development, there is an increase in heavy truck traffic on the roads leading to the pads as equipment and material required for construction and hydraulic fracturing of wells are moved to and from the pads. The types of equipment required include bulldozers, graders, and dump trucks for access road and site clearing; large flatbed trucks for movement of specialized equipment; drill rigs for well construction; and sand and water trucks for well stimulation.

As illustrated in Figure 6 (Anadarko, 2015), the advent of directional drilling made it possible to drill horizontal wells, dramatically reducing the surface impact of oil and gas development. When only vertical wells were used, within a 2.5 km^2 area there typically would have been 4-16 vertical wells, but there may have been as many as 32 wells. Today, many horizontal wells can be drilled from a 0.03 km^2 well pad. A single, 2-km-long, horizontal well can drain approximately 0.6 km^2, so a pad containing 16 wells could drain a subsurface area of up to 9 km^2. Consequently, the surface disruption associated with a commercial-scale development is very much smaller than was the case using vertical wells.

Figure 7 (Statoil, 2010) shows horizontal wells extending in opposite directions from a well pad. In such a configuration, a small number of well pads can provide complete coverage of a large underground resource area with little surface disruption. A single drilling and production site (i.e., a "pad") can accommodate 10-20 horizontal wells. The reduction in impact on infrastructure needs and land disturbance is significant. Instead of 30-60 pads, each having one vertical well, a single pad with multiple horizontal wells simplifies transportation issues, reduces the number of access roads, and allows development to continue at one pad for longer periods of time instead of moving more frequently between pads.

In the Horn River Formation shale gas play (BCOGC, 2014b) in British Columbia, 16 wells per pad draining approximately 6 km^2 are common. In the Bakken Formation in North Dakota, the trend is toward longer horizontal well sections, typically 3 km long. In addition, there tend to be more wells per pad because of the ability to drill several layers of wells from a single pad. Several layers of wells are required because the resource is contained in zones of moderate thickness that exceed the drainage volume of a single layer of wells. As a result, hydraulic fracturing of these thicker zones must be done layer-by-layer. Similarly, in the potential shale gas development at Frederick Brook, New Brunswick, since the shale resource exceeds 1 km in thickness (NBONG, 2015), more than one layer of horizontal wells will be needed to achieve effective stimulation. In the case of the Green Point shale, *"well evidence shows that these units [oil-rich shale] are roughly 1000 meters thick in the middle of the bay [Port au Port Bay]"* (Morning Star, 2014).

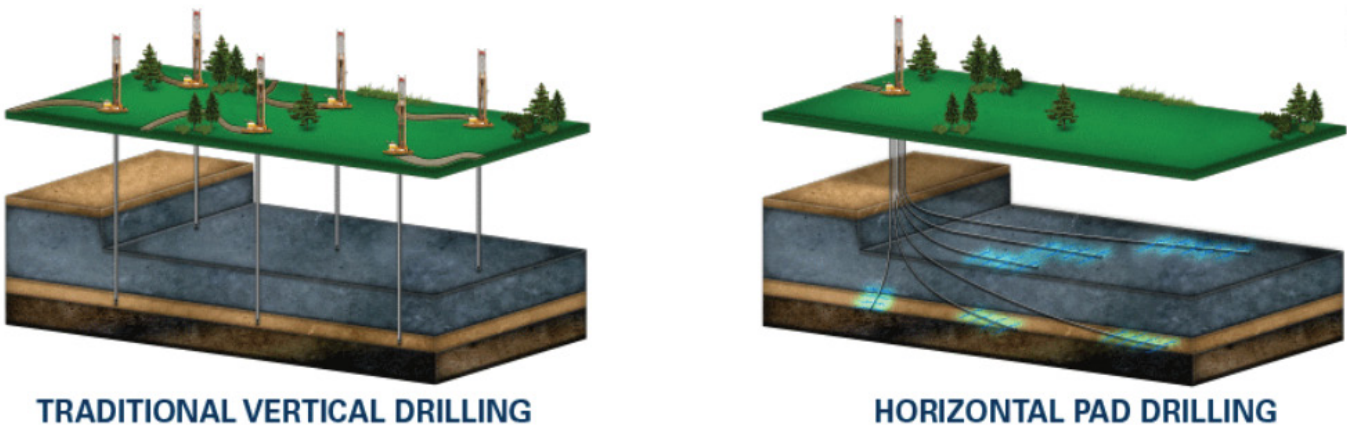


Figure 6. Comparision of vertical and horizontal drilling (Anadarko, 2015).

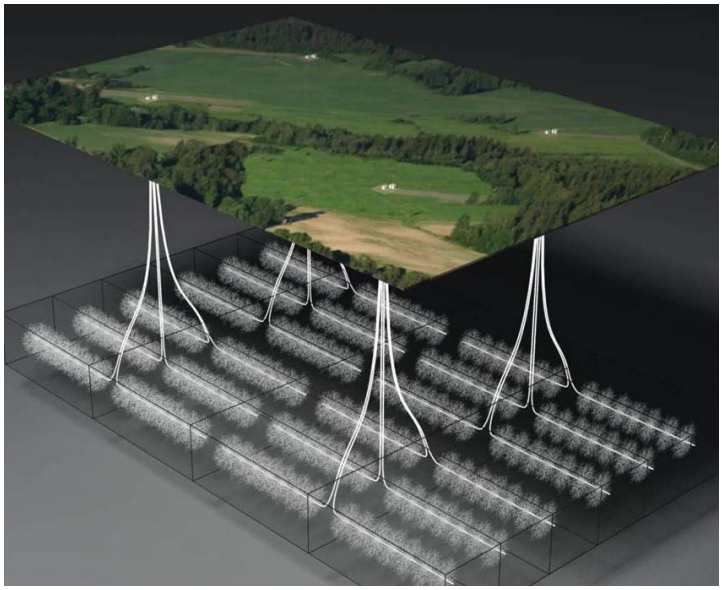


Figure 7. Illustration of multiple wells drilled on multiple well pads (Statoil, 2010).

Given the continued advances in drilling and hydraulic fracturing technology, if the Green Point shale is ever developed, the oil resources under Port au Port Bay might, for the most part, be accessed from land sites. With increased well length capability, it is likely that the number of wells per pad will continue to increase, thereby decreasing the land disturbance on a per well basis.

5.2 Approaches to Well Stimulation by Hydraulic Fracturing

Hydraulic fracturing refers to any *"process of fracturing rock formations with water-based fluids"* and includes foams and emulsions in addition to water (Gandossi, 2013). There is extensive use of water-based hydraulic fracturing fluids in Canadian and the U.S. shale developments, which are *"complex reservoirs that are brittle and naturally fractured and are tolerant of large volumes of water"*.

As discussed in (Fracfocus, 2016), over 98% of hydraulic fracturing fluid is water and proppant, with the balance being various additives as illustrated by Figure 5 in Section 2.2 of this report. The purpose of the proppant, which is usually sand, is to wedge or prop open new or existing fractures in the rock formation.

When a well is stimulated by hydraulic fracturing, known as a "treatment", the treatments are *"sequenced to meet the needs of the formation"* (Fracfocus, 2016). The following sequence of treatments are used in the Marcellus shale in Pennsylvania:

- an **Acid Stage** uses a dilute acid mixed in water to clean the wellbore of debris and to etch the rocks to enhance flow near the wellbore;
- a **Pad Stage**, which does not use proppant, improves the flow and placement of proppant material in subsequent treatments by filling the wellbore with slickwater (see Section 5.2.2) solution;
- a **Prop Sequence Stage**, which may include several treatments with varying sized proppant particles, injects water combined with proppant material to keep the fractures open; and
- a **Flushing Stage** injects fresh water into the wellbore to flush out excess proppant.

The sequence noted above is typical of that used in the Marcellus shale, although for other developments, *"while the process remains essentially the same, the sequence may change depending upon unique local conditions"* (Fracfocus, 2016).

The choice of additives will depend on the local conditions. Furthermore, *"the exact 'blend' and proportions of additives will vary based on the site-specific depth, thickness, and other characteristics of the target formation"* (Fracfocus, 2016).

As discussed in Section 5.5, the sequence described above is carried out using a staged fracturing approach, where short sections of the horizontal well, known as stages, are sequentially stimulated so as to optimize the fracturing results. For example, hydraulic fracturing a single, 3-km-long, horizontal well may be carried out along 20-30 stages starting from the far end of the wellbore.

The remainder of this section provides an overview of some of the approaches used in hydraulic fracturing treatments.

5.2.1 Gel Fracturing

To ensure proppant penetrates into the fractures that are opened up during hydraulic fracturing, the fracturing fluid is often rendered viscous (i.e., similar to the consistency of syrup) by the addition of natural polymers. This may include, for example, natural, non-toxic gums extracted from trees, such as guar gum or xanthate gum. These gums are often combined with crosslinkers, which join together smaller polymer molecules into larger molecules to achieve a much higher viscosity. High viscosity is also achieved by vigorously mixing the polymer in water, which entangles the molecules just before the proppant is added.

Because the gels are biologically degradable by bacteria that exist in make-up water and in the rocks, a biocide is often added to the hydraulic fracturing fluid. The biocide inhibits the fermentation of the organic matter, mitigating problems during production, such as fouling, biofilm generation, and souring. The amount of biocide used is in the order of a few grams per tonne of fracturing fluid. Some biocide degrades rapidly upon exposure to oxygen, or is easily adsorbed by the minerals in the reservoirs.

The biocide can also be further diluted by formation water once the well begins producing oil and gas. Formation water is naturally occurring water that is trapped within the pores of the shale. Following dilution, any remaining biocide presents low risks. It is important, however, to be aware of chemical interactions and the behaviour of various types of biocides. Since they are a critical component of hydraulic fracturing fluids, when selecting a biocide it is important to understand the potential fate and toxicity, as well as knowledge gaps that could impact effectiveness for a particular application (Kahrilas, et al., 2015).

During well stimulation, the gel and proppant mixture is pumped into the wellbore. The viscosity of the gels must be "broken" in the rock after the proppant has been placed into the fractures, allowing oil and gas to flow freely. The large entangled molecules must be "unwound", which happens in part through natural processes provided the gel is no

longer moving. The unwinding of the entangled molecules is also facilitated by viscosity breakers, which are chemicals that help reduce the gel viscosity after the gel stops moving. The viscosity breakers have a delayed action, so that the fracturing fluid retains its properties long enough to open the fracture and place the proppant, and yet breaks down into a low-viscosity liquid. The low-viscosity fluid can then be flushed from the fractures to allow oil and gas to flow during production.

A typical gel fracture fluid might contain approximately 90% make-up water, 1% guar gum, less than 1% other agents, such as viscosity breakers and crosslinkers, and approximately 8-9% proppant. The proppant content will change over the hour or two of gel fracturing that takes place. For example, proppant-free fluid may be pumped for some time before proppant is added, and the concentrations may change depending on the fracture design goals. In general, gel fracturing volumes are substantially lower than slickwater fracturing volumes, which are discussed below.

Foams specifically formulated for fracturing purposes have some advantages in carrying proppant into the fractures. To make a fracturing fluid foam, it is necessary to add carbon dioxide (CO_2), or some other inert gas. There is also a need to add a foaming agent, known as a surfactant, to reduce the surface tension of the fluid. Chemical agents are also added to stabilize the foam long enough for it to perform its function in the reservoir. Once the proppant is placed in the reservoir, it is important that the foam degrades into a liquid so it can return up the wellbore.

Other additives can be used to achieve more effective fracturing, depending on circumstances or properties of the formation or the make-up water. For example, if there is concern that swelling clay minerals will impede the success of the hydraulic fracture stimulation, brine may be added. Iron compounds in the make-up water can be scavenged by adding citric acid to the fracturing fluid. Scale formation can be controlled by adding a scale inhibitor to the fracturing fluid. If leakoff of fracture fluid to the formation is a problem, diesel fuel or finely ground minerals, such as calcium carbonate, may be added to partially plug the pores through which leakoff is taking place.

Most crosslinkers, viscosity breakers, foaming agents, and biocide agents are classified as hazardous industrial chemicals, especially in the concentrated form in which they are delivered to the site. The materials, therefore, must be treated with care during transport, storage, and use, following mandated procedures and safety practices required by regulatory agencies and federal or provincial regulations.

5.2.2 Slickwater Fracturing

Slickwater fracturing involves adding a small amount of an industrial polymer, called a polyacrylamide compound, into the make-up water. This approach does not require the use of gels and the associated crosslinkers. Other chemicals, such as surfactants, scale inhibitors, and biocides, may be added for the reasons discussed in Section 5.2.1.

The technique is termed "slickwater" because the very small concentrations of polymer make it easier for water to flow through the thin channels opened up by hydraulic fracturing. While the viscosity of the water is unchanged with this technique, the polymer molecules reduce the friction in narrow channels, requiring less energy to pump the same amount of fluid. This leads to a reduction in pumping costs and allows for increases in treatment volumes. Substantially higher injection rates and pressures can be achieved to improve fracturing results. Slickwater fracturing is thought to be conducive to opening up a more complex pattern of natural flow paths, thereby accessing larger shale volumes. As a result, the well not only produces at a better rate, but there may be an increase in the amount of oil recovered from the reservoir.

Proppant is also added to slickwater fracture treatments, although in lower concentrations than for gel fracturing. This is because the capacity of slickwater to carry the proppant is far smaller than for a viscous gel. Proppant tends to settle in water because it is denser, limiting both the proppant concentration and the height that proppant may be carried above the fracture point. Because of the lower viscosity of the fracturing fluid, the hydraulic fractures in the wellbore region for slickwater treatments are thin compared to gel fracturing. As a result, many companies carry out

fracturing at each stage in several sub-stages. Stimulating a single stage may start with a large volume of slickwater and a small amount of proppant for an hour or two at a rate of 10-12 m^3/min. This would be followed by a gel fracture at lower rates and for a shorter time, but with higher concentrations of proppant.

While different companies employ different hydraulic fracturing strategies, large, high-rate treatments are generally preferred when the shale resource is characterized by thick zones at great depth. In general, other additives are not normally used in slickwater fracturing, but the addition of carbon dioxide (CO_2) gas is common because a "CO_2-charged" fluid is thought to lead to better fracturing in some circumstances.

5.2.3 Acid Treatment or Acidizing

Acids may be used in hydraulic fracturing, particularly in cases of carbonate rocks, such as limestone, or in low-permeability shale containing calcium carbonate ($CaCO_3$). Many of the materials that are referred to generically as shale have some component of calcium carbonate. The purpose of using acid is to dissolve a small amount of the carbonate mineral, generally near the wellbore and on the surfaces of the fractures, to increase the flow path for oil and gas. As a result of acid treatment, the well is usually more productive.

A common use of acids is to restore the flow capability of the wellbore following other fracturing treatments. Acid treatment near the wellbore (within a radius of 1 m to 2 m) may be completed after fracturing or years later to unplug a well. During production of oil and gas, blockages near the wellbore can develop from the migration of small amounts of clay toward the well and by the precipitation of chemicals from formation water flowing into the well.

Acids are used in far smaller volume treatments compared to slickwater or gel fractures because of the cost. As the acids dissolve minerals in the rock, they are also used up (i.e., chemically consumed) in the process. Consequently, they do not return to surface as strong acids, but rather as weak acids containing dissolved minerals and metals. Because acids are relatively quickly used up near the wellbore, the beneficial effects are almost impossible to achieve if the acid has to flow any significant distance from the wellbore. Corrosion as a result of the acid liberates small amounts of heavy metals naturally occurring in shale that is rich in organic matter. These shales also tend to have higher concentrations of naturally occurring radioactive metals. Consequently, the acidic fluids that return through the wellbore to the surface have to be handled as hazardous materials.

5.3 Recycling and Treatment of Fracture Fluid Flowback

During well stimulation some of the injected hydraulic fracturing fluid flows back up the wellbore when the pressure in the producing well is dropped (USEPA, 2015). Not all of the fluid injected flows back in a short time, however, and some never flows back. The fluid that initially returns up the wellbore is known as "flowback".

Early flowback typically constitutes 20% to 45% of the injected fluid volumes and is produced within a few hours of injection. Another 20% to 45% of the injected fluid volume returns up the wellbore to the surface along with the production fluids (oil, gas, and formation water). The water that flows up the wellbore along with oil and gas is known as "produced water". In this report, the term "wastewater" refers to both flowback and produced water.

Some of the fracture fluid that does not initially return as flowback becomes permanently trapped in very thin fractures and small pores in the shale. Some fluid is trapped because it is absorbed by clay minerals that have small adsorptive capacities.

The quantity of dissolved materials (e.g., salt, residual fracturing chemicals, and heavy metals) is affected by many factors. They include the nature of the formation being fractured (e.g., oil or gas, saline or fresh water, nature of the saline fluids, presence of radioactive elements), the fracture fluid formulation, and the time that the fracture fluid spends in the formation. Flowback cannot be simply discharged into lakes or streams. Rather, it must be treated to

standards that depend on its composition. For example, flowback from slickwater fracturing is chemically different from flowback from gel fracturing. As such, depending on the amounts of dissolved materials, they may need to be treated differently.

Three common approaches to handling flowback include injection into deep disposal wells, wastewater treatment, and re-use (USEPA, 2015). Deep well disposal is widely used to handle produced water from conventional oil and gas production. World-wide, about 3 m^3 of formation water is produced per 1 m^3 of oil recovered. The Green Point shale will also produce gas and produced water along with oil if commercial production is undertaken. While the fractions of produced water and gas are unknown at present, testing and some production will allow the gas and produced water rates to be determined. It is expected that the ratio of produced water to oil would be comparable to that typical of the Middle Bakken Region, which has a produced water to oil fraction of 0.77 (i.e., 0.77 barrels of produced water per barrel of oil recovered). In Alberta, there are several thousand deep disposal wells for produced water, as well as other wells that dispose of mixtures of produced water and acid gas (CO_2) and traces of sulphides (H_2S).

Prior to deep well disposal, the flowback is clarified to remove solids. The clarified flowback is injected into a porous subsurface formation that is deep enough to ensure that there is no interaction with the shallower potable groundwater. Usually disposal is into a saline aquifer that is 1 km or more under the surface and which originally contained only salty water. In comparison, fresh groundwater aquifers are generally found at depths no greater than 300 m. In other cases, flowback is re-injected via offset wells into the formation that produced the oil in order to push more of the oil out of that formation.

In Western Newfoundland where the Green Point shale might be developed, it is uncertain whether there are porous subsurface formations that can accommodate large volumes of water for disposal. It may be possible, however, to inject limited volumes of flowback or produced water. This uncertainty can only be resolved with a more detailed assessment of the subsurface geology of any potential disposal locations.

Treatment of flowback and produced water is another option for handling wastewater. A comprehensive wastewater management strategy is critical since waste fluids from hydraulic fracturing activities differ substantially from wastewater typically handled by municipal wastewater treatment facilities.

A survey of oil and gas wastewater management approaches used in the Marcellus region suggests that water reuse for future hydraulic fracturing treatments is a possible strategy. One approach is to treat the wastewater so that the quality is suitable for re-use (Schmid & Yoxtheimer, 2015). There are a variety of physical and chemical treatment technologies that can be safely applied to wastewater. These include precipitation-based technologies, distillation processes, degreasing technologies, and oxidation processes. Treatment options for wastewater also include low energy desalination, thermal distillation, and crystallization technologies. The wastewater management system must be designed for the final effluent composition, taking into account flow rates so that treatment design is coupled with an appropriate water monitoring strategy. At some point, however, treated and recycled wastewater requires disposal.

Re-use of flowback for further well stimulation may reduce, or potentially eliminate, the need for extensive treatment if deep well disposal in sufficient quantities and rates is not possible. Generally, flowback is filtered and softened because "hard" water, which contains calcium and magnesium, requires substantially more chemicals to achieve the desired condition for re-use. Some residual saline water (i.e., salt water) is produced through filtering and softening and will require disposal. Flowback re-use would reduce the production of residual saline water and, in turn, reduce operational costs. This does not, however, address the issue of how to handle produced water.

5.4 Enhanced Recovery Processes

Unconventional oil and gas reservoirs contain fine-grained rock that is intersected by a network of natural fractures. The natural fractures, some of which have been opened up by the hydraulic fracturing process, provide pathways for the flow of oil and gas. The blocks of rock between the natural fractures, however, have extremely low permeability and oil and gas does not readily flow through the blocks. After the initial hydraulic fracturing treatments, a typical production period for a well may only yield a small percent of the oil that is in the fractured shale. The remainder of the oil is trapped or flows too slowly out of the shale for the well to be economically viable. Many well-known enhanced oil recovery techniques that are used for conventional oil and gas production will not work in unconventional oil and gas reservoirs because the pores are too small, and permeability too low, to allow the conventional enhanced recovery agents to effectively penetrate into the rock to improve the flow of oil and gas.

Companies in the unconventional oil and gas industry in Alberta and Saskatchewan are undertaking limited trials of new techniques to increase the production rate and the oil recovery from unconventional wells that are no longer economically viable. The primary objective of these enhanced recovery methods is to increase the surface area of the fractured rocks in the shale reservoir. By increasing the surface area of the rocks, more oil will slowly diffuse out during the lifetime of the well.

One approach to increasing the surface area of the rocks is to repeat the hydraulic fracturing treatment. Refracturing is now being used in wells that are only a few years old to trigger another phase of economically viable oil production from the wells.

To get more oil out of the rock, or to accelerate the flow, different techniques might be used. These include fracturing with nitrogen (N_2), liquid carbon dioxide (CO_2), and propane. Carbon dioxide (CO_2) injection is of particular interest for several reasons (NEORI, n.d.). It has very low viscosity, so it is better at entering into small cracks and pores than water-based liquids or even most hydrocarbon liquids. Also, light oil and liquid CO_2 are mutually soluble at high pressure. This reduces the viscosity of the oil, allowing it to flow more readily into the fractures in the rocks. As the CO_2 mixes with the oil, there is an increase in volume, creating an internal expansion that helps force oil through the fractures. Finally, CO_2, when available, is generally much cheaper than light hydrocarbons or other agents that might be used to enhance fluid flow.

5.5 How Well Stimulation Using Hydraulic Fracturing Is Done

Figure 8 shows a Google Maps image of a series of multi-well pads at a Marcellus shale gas well site in Lycoming County, Pennsylvania. The image is annotated to highlight the locations of the well pads; pipeline rights-of-way; well pad access roads; public roads; and water impoundment ponds, which are sometimes used to temporarily store wastewater or make-up water. Figure 9 shows a close up Google Maps image of one of the well pads where drilling is being carried out.

When all the wells on the pad have been drilled, the process of "well completion" is carried out and the well is cased, cemented, equipped with wellheads and valves, perforated, and stimulated. A well that is ready to start production is referred to as having been "completed". Prior to commencing stimulation activities, the site is cleared of large drilling equipment and prepared for hydraulic fracturing. Figure 10 shows a wellhead that has been prepared for well stimulation.

Figure 11 illustrates the types of equipment that operate on a well pad during well stimulation, while Figure 12 is a picture taken on a well pad in Pennsylvania while a well was being hydraulically fractured.

An approved water source near the well pad supplies make-up water, sometimes from a water impoundment pond on site that is refilled by pumping from a more distant source. Chemicals and proppant in sufficient volumes are stored

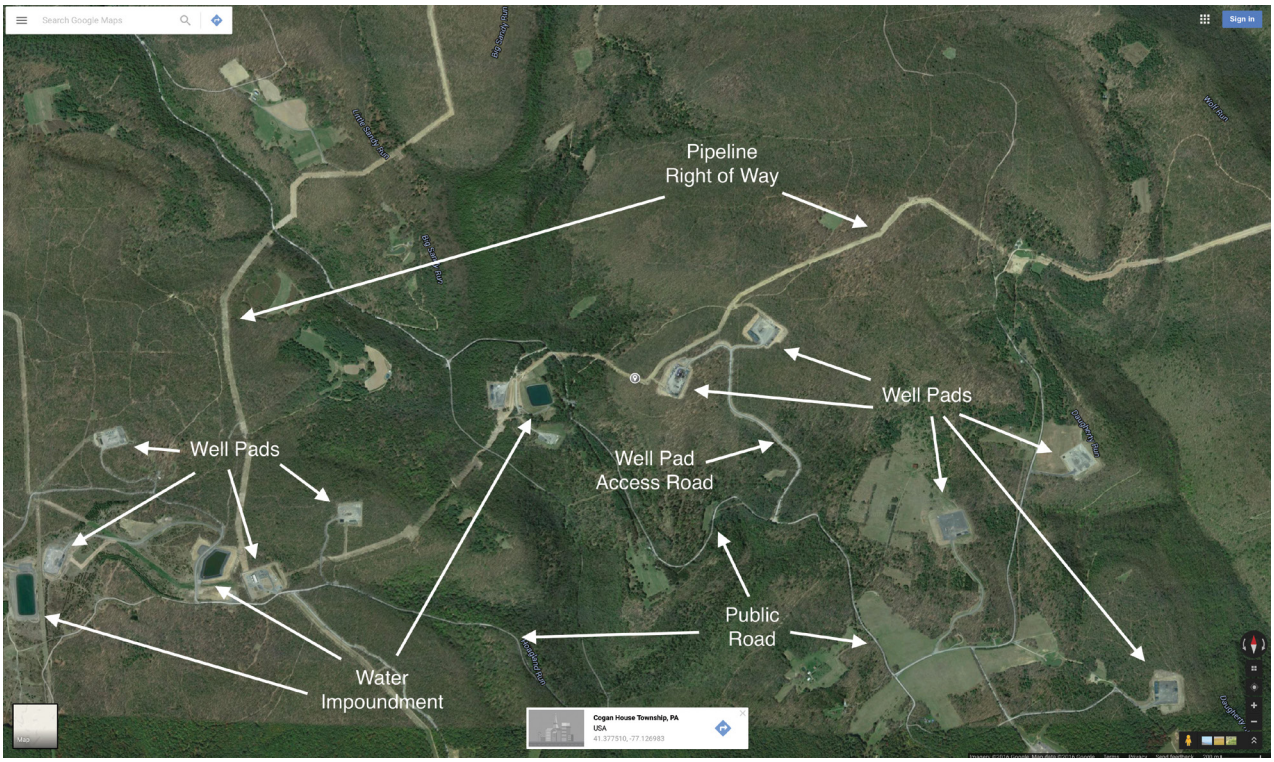


Figure 8. Google Maps view of hydraulic fracturing sites in Lycoming County, Pennsylvania.

Figure 9. Google Maps view of drilling operation at a site in Lycoming County, Pennsylvania.

Figure 10. Wellhead ready for hydraulic fracturing.

on the well pad, as close to the wellheads as feasible, and very close to the blending units that mix the materials in the desired proportions for immediate injection.

During well stimulation, pumping trucks are lined up, usually in two rows, so that it is easy to link them all together with high-pressure hoses. Because high injection rates and fluid pressures are thought to be the best stimulation approach, many trucks are needed to provide the power necessary to inject the fracturing fluid. The amount of power needed is a function of well-specific factors, including the depth of the horizontal section of the well, the required viscosity of the fracturing fluid, the design of the wellbore (e.g., tubing and casing diameters), the selected treatment approaches, the proppant content, and the desired fracturing fluid injection rate.

Well stimulation begins by preparing the hydraulic fracturing fluid by mixing water with appropriate quantities of proppant and other additives in blending units (USEPA, 2015). As previously noted, and as illustrated in Figure 13, hydraulic fracturing of a well is carried out in stages so that during each stage a small volume around the wellbore is fractured, starting with the stage that is nearest the "toe" of the well and working back toward the "heel".

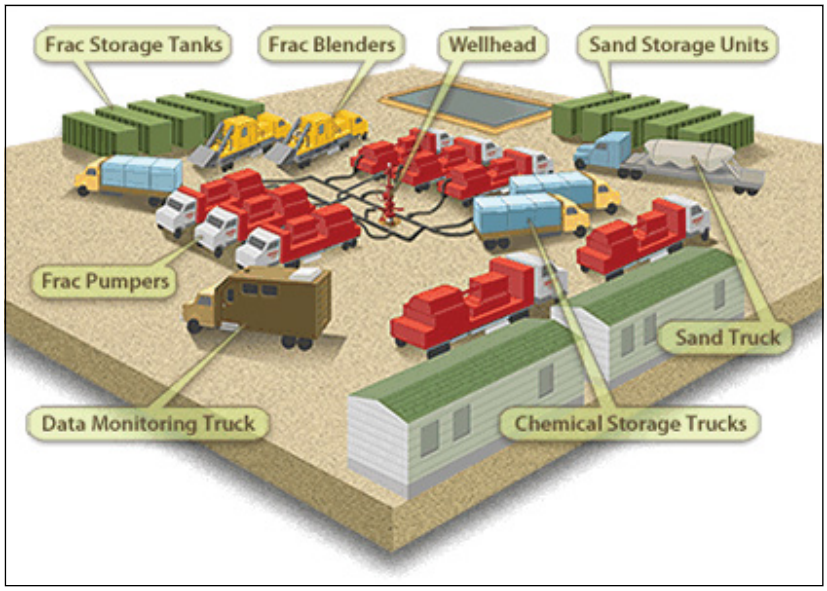


Figure 11. Illustration of equipment operating on well pad during hydraulic fracturing of a well (Fracfocus, 2016).

Figure 12. Pumping trucks and other equipment on well pad.

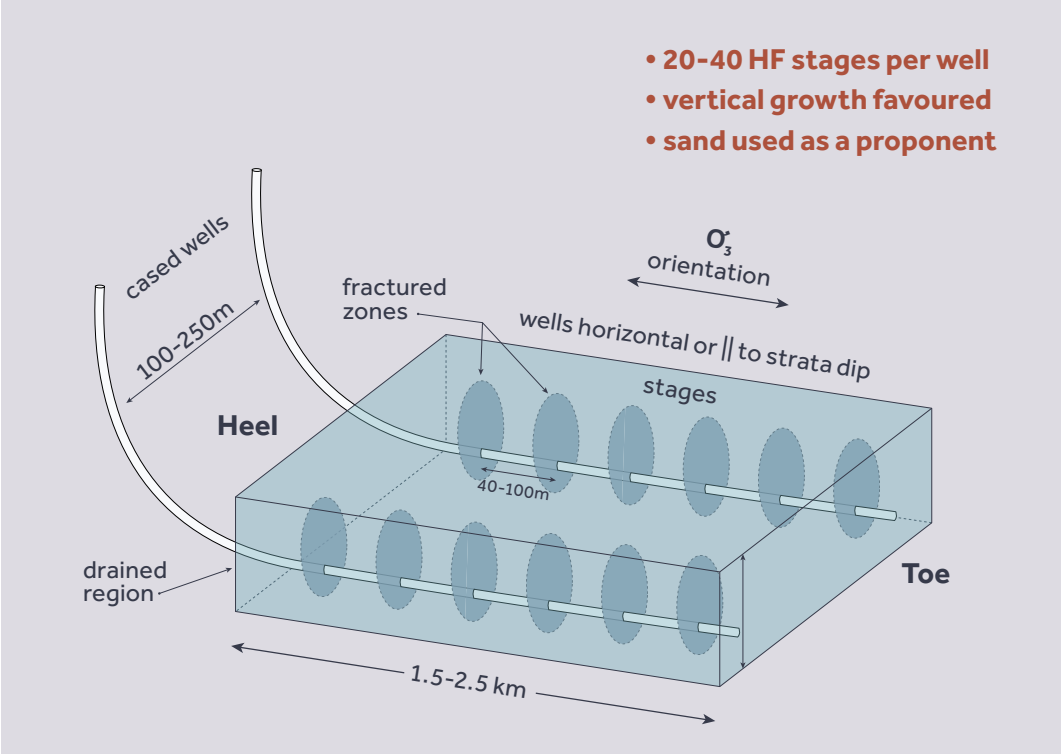


Figure 13. Horizontal well illustrating stages of hydraulic fracturing (Dusseault, 2016).

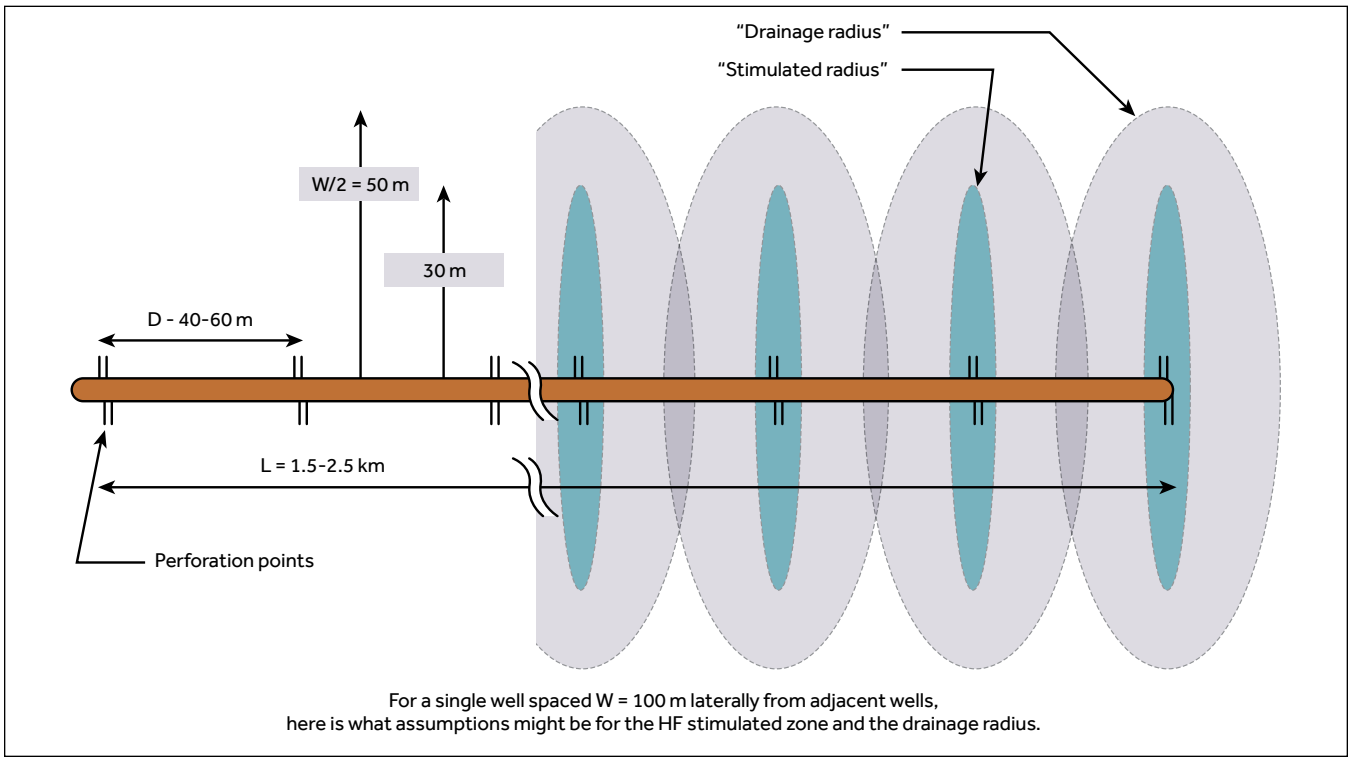


Figure 14. Illustration of fractured zones and drainage radius (Dusseault, 2016).

As illustrated in Figure 14, the size of the fractured zones, the separation between the wellbores, and the spacing between stages along a wellbore are parameters that are selected to optimize recovery of oil and gas. These parameters are determined from the results of trial fracturing and geomechanical modelling that is done as part of the design of a well plan. During production, the fractured zones serve to drain the oil, gas, and formation water in the vicinity of the horizontal wellbore. Note that the drainage volume is somewhat larger than the fractured zone.

As discussed in Section 5.2, each stage is subjected to a sequence of hydraulic fracturing treatments with the hydraulic fracturing fluid composition varied to suit the local conditions and to optimize the effectiveness of the process. During each treatment, the hydraulic fracturing fluid is fed continuously to pumping trucks that pump the fluid, using high pressure and flow rates, into the wellbore to feed a single stage in the horizontal well. This continues until the stage has been completed. All excess material in the wellbore is flushed so that stimulation of the next stage of the well can proceed without delay. The next stage is prepared, and the treatments proceed until all stages have been completed. The process of hydraulically fracturing a single well can take 5-8 days. Fracturing all of the wells on a 16-well pad could take three to four months following drilling and installation of the wellhead and well casings.

Once all stages have been fractured, steps are taken to turn the well into a producing well. For example, if a well produces oil, gas, and water, as would be the case for the Green Point shale, an electrical pump is installed down-hole to pump, or lift, the fluids.

5.6 The Production Phase of Operations

Once all of the wells on a well pad are completed, the pad is partially rehabilitated and prepared for long-term production. This is done *"by installing well pumps and tubing using a service rig; by installing flowlines, tanks and other equipment needed to support the production phase; and, by making provision for future re-stimulation of wells or other well entry activity such as re-installation of pumps"* (Dusseault, 2016).

When a well goes into production, there is much less activity associated with the well. Figure 15 shows a well pad containing 10 producing gas wells and related processing equipment near Williamsport, Pennsylvania. The 10 wellheads are seen in the background while the 10 separators in the foreground are used to meter the fluid production from each well and to separate the oil and gas. The produced fluids are carried by small diameter buried pipes (i.e., flow lines) to a central processing facility where the produced water and other by-products or waste products are removed. Since there was a plan to add additional wells to the well pad shown in Figure 15, the large footprint of this pad was maintained.

Producing wells are connected together by gathering lines that collect the petroleum products from the wells and transport them to a central transportation pipeline. In the context of Western Newfoundland, this central pipeline would carry the product to a marine loading terminal that would bring the oil to market. There would need to be *"hydrocarbon processing facilities built on some of the sites for treatment and transshipment of fluids (gas, oil, produced water)"* (Dusseault, 2016). These processing facilities would separate the oil, gas, and produced water that flows from the wells. The associated gas would be used locally, exported, or reinjected, while the produced water would be disposed of or reused in subsequent hydraulic fracturing treatments.

When the wells are in production, most traffic to and from the pads is in support of monitoring and maintenance activities. Depending on how produced water is being handled, it may also be necessary to transport produced water from the pads by tanker trucks. A producing well may be re-entered several times during its production history to treat near-wellbore blockages, to re-fracture some stages so that production can be enhanced or re-established, to carry out well servicing, or to maintain or replace downhole sensors or pumps. These activities require much less equipment compared to the primary hydraulic fracturing treatments. For re-entry activities smaller service rigs and fewer trucks are normally required.

Figure 15. A producing well pad containing 10 gas wells near Williamsport, Pennsylvania.

5.7 Site Reclamation and Remediation

After a period of oil and gas production, the productivity of an unconventional oil and gas well declines to the point where it is no longer economical to keep the well in production. At that point, the well may be suspended or abandoned (i.e. decommissioned). Complete decommissioning and site rehabilitation, including restoring vegetation, may be delayed since new enhanced oil recovery methods could make it feasible for a suspended unproductive well to become productive for another period of time.

Decommissioning requires all above-surface casing and equipment to be removed (Campbell & Smith, 2013). The well is then "plugged" with several cement plugs that prevent leaks from or into the wellbore and that isolate zones within the wellbore. Appendix D notes that:

> *"Well decommissioning involves making sure that the wellbore possesses integrity (no leaking of fluids), rectifying any problems that might exist, then placing a series of sealing plugs, usually only within the innermost open part of the well, to insure that there is no pathway for fluids to migrate from one zone to another, or to migrate up to the surface"* (Dusseault, 2016).

Once a well has been plugged, it is also the responsibility of the operator to restore the site. A decommissioned oil and gas site in New Brunswick *"must be restored in such a manner that its capability to support different land uses is similar to its pre-construction capability"* (NBRFI, 2013). Prior to construction of an oil and gas site, a site assessment

is completed. This includes assessing the landscape, including contours and drainage, and the vegetation so as to establish a standard to compare against for future site restoration. Following decommissioning, site restoration involves removing all debris, imported fill, and topsoil under the footprint of any oil and gas activities; stabilizing any slopes; restoring land contours; restoring vegetation with only native species; and restoring drainage patterns. Infrastructure of public value, such as roads and bridges, may be transferred to local authorities.

Once a site has been restored by the operator, *"landscape, vegetation, and soil assessments must be completed to verify the effectiveness of the site restoration"* (NBRFI, 2013). In addition, any sites utilized for oil and gas activities are required to have an environmental site assessment completed, and any soil or groundwater contamination must be remediated. Alberta, British Columbia, and Saskatchewan have similar requirements.

Through a Reclamation Certificate Program, Alberta requires professional sign-off for all remediation and reclamation work and holds industry liable for post-abandonment issues (ABGOV, 2014). Under this program:

> *"The industry liability period for surface reclamation issues (topography, vegetation, soil texture, drainage etc.) is 25 years and the company is required to resolve any reclamation issues that arise within the 25-year period. The liability reverts to the government after the industry liability period has expired. Liability for contamination issues remains with the company in perpetuity".*

Long-term well integrity is an ongoing concern for wells that have been decommissioned (CCA, 2014) (NSIRPHF, 2014) (NBCHF, 2016) (Davies, et al., 2014) (Jackson, et al., 2013) (Soeder, 2015) (Dusseault, et al., 2014) (Ingraffea, et al., 2014). Well integrity issues during development, production and following decommissioning are discussed in more detail is Section 11.4 and in Appendix D (Dusseault, 2016).

6 THE NEWFOUNDLAND AND LABRADOR POLICY AND ECONOMIC DEVELOPMENT CONTEXT FOR UNCONVENTIONAL OIL AND GAS DEVELOPMENT

In the Panel's opinion, there are two key provincial policy frameworks within the Province of Newfoundland and Labrador that are important to consider in reference to unconventional oil and gas development. These are Focusing our Energy (NL Energy Plan, 2007), the province's Energy Plan, and Charting Our Course (NL Climate, 2011), the province's Climate Change Action Plan. It is also important to consider where unconventional oil and gas development fits within regional economic development plans for the regions that are most likely to be affected by such developments.

6.1 Energy Plan

In his introduction to the Energy Plan, and in reference to Newfoundland and Labrador's natural resources, the then Premier noted:

> *"The one and only responsible way to ensure we are properly prepared to seize every economic benefit from these resources is to move forward on the basis of a long-term strategic Energy Plan for our Province"* (NL Energy Plan, 2007).

In the Energy Plan, the Government of Newfoundland and Labrador states that the province will meet its future domestic energy needs from renewable energy sources, such as hydroelectricity from the upper and lower Churchill River projects. Non-renewable energy resources, such as oil and gas, would be developed primarily for export to other jurisdictions and to generate economic return to the people of the province. The economic return would include, but would not be limited to, government revenues, local job creation, infrastructure investments, business growth, and improvements in the demographic profile of the province.

Furthermore, the fundamental principles of the Energy Plan include:

- sustainability – energy developments must be environmentally and economically sustainable;
- control – Government must exercise appropriate control over the development of the resources to ensure that these resources are managed and utilized in the best interest of the people of Newfoundland and Labrador; and
- cooperation and coordination – resource development will add value through cooperation and coordination with key stakeholders and partners.

While there are many definitions of "sustainable development", the Panel is inclined toward the perspective of United Nations World Commission on Environment and Development:

> *"Yet in the end, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs"* (Brundtland, 1987).

The Energy Plan goes on to highlight:

> *"Long-term and comprehensive stewardship of our energy resources is critical to the future of our people, our environment, and our economy. As we have learned over the course of our history, the choices and decisions we make today will significantly impact future generations. It is therefore essential we base our future actions on the clearest possible understanding of our needs and the long-term implications of our decisions. Getting this right is especially important for our non-renewable resources as once these resources are depleted, they are gone forever"* (NL Energy Plan, 2007).

Following from this principle is the implicit commitment that the development of unconventional oil and gas projects requires balancing the benefits arising from utilization of the resource against negative social, health, and environmental impacts that may result. Furthermore, getting the development "right" also means enabling the benefits of long-term infrastructure that may be leveraged for future generations of Newfoundlanders and Labradorians.

The Energy Plan notes that development of the province's non-renewable resources generates near-term economic capacity to invest in the development of renewable energy resources. Specifically, the Energy Plan reads:

> *"The Provincial Government believes that the best interests of Newfoundland and Labrador are served by converting the value of our non-renewable energy resources into renewable, environmentally–friendly sources of energy that address our current social and economic priorities and provide a legacy for future generations. We will use our energy resources to contribute to building a strong, sustainable economic base, while ensuring we are an environmentally–responsible province"* (NL Energy Plan, 2007).

Whereas oil and gas resources feature prominently in the Energy Plan, including reference to resources in Western Newfoundland, the plan predates consideration of unconventional oil and gas development. As such, it is silent on hydraulic fracturing in Western Newfoundland. The prospect of hydraulic fracturing in Western Newfoundland was raised in the context of the 2014 Strategic Environmental Assessment Update for the Western Newfoundland and Labrador offshore area prepared for the C-NLOPB. This update includes an analysis of *"potential environmental issues which may be associated with any future oil and gas exploration and/or development activities in the area"* (Amec, 2014). Specific reference was made to proposals to conduct hydraulic fracturing in Western Newfoundland.

The Energy Plan puts forward some important principles related to energy resource development within the province. For instance, it raises the possibility of Government investments in support of petroleum exploration in Western Newfoundland, with the prospect that these investments could be used to leverage equity in future onshore

projects. Of particular relevance to the oil and gas resources in Western Newfoundland is the Petroleum Exploration Enhancement Program (PEEP, 2015), which supports the acquisition and assessment of seismic data relevant to onshore projects. Such a public investment in developing a greater understanding of the geology of potential resources is emphasized in the Energy Plan as the basis for an equity interest in onshore projects. The Energy Plan also notes that, in addition to potential future revenue from an equity position, such equity ownership serves as an influence mechanism for the province to *"ensure first-hand knowledge of how resources are managed, to share in that management, to foster closer government/industry alignment of interests, and to provide an additional source of revenue"* (NL Energy Plan, 2007).

6.2 Climate Change Action Plan

The Energy Plan (NL Energy Plan, 2007) intersects with the Government's Climate Change Action Plan (NL Climate, 2011) as illustrated by the following statement from the Energy Plan:

> *"We will continue to pursue the development of our oil and gas resources and use proceeds from these projects to support the development of renewable energy infrastructure that will enable us to have a sustainable clean-energy future. ... We will also maintain strict environmental rules to minimize impacts on the environment from energy developments"* (NL Energy Plan, 2007).

This speaks to the need to consider the impacts of greenhouse gas (GHG) emissions from new energy developments within the context of the province being a net producer of clean energy by 2020. In particular, the Energy Plan states:

> *"By 2020, we envisage a Newfoundland and Labrador that is both a highly efficient consumer of clean energy, and a net producer of clean energy. Development of our vast renewable energy resources in an environmentally sustainable manner will bring lasting benefits to the people of this Province and ensure our place as a net contributor to a healthier global climate"* (NL Energy Plan, 2007).

The Lower Churchill hydro-electric project contributes to the province's objective of being a net producer of clean energy. The extent to which the province can achieve its goal, while continuing to develop non-renewable energy resources that have negative climate change impacts, is not addressed in the Energy Plan.

In July 2015, the Government of Newfoundland and Labrador was among 22 signatories to the Climate Action Statement (CAS-CSA, 2015). In a press release celebrating the signing of that agreement, the then Minister Responsible for Climate Change and Energy Efficiency stated that *"we consider climate change to be an urgent global problem and we are committed to being part of the solution"* (MCCEE, 2015). The then Minister went on to note *"the province's intention to bring forward a framework to reduce gas emissions from large industry"*. Newfoundland and Labrador also signed the Compact of States and Regions, which requires participating governments to make a public commitment to reduce GHG emissions and to report annually on a standard set of GHG data (CSR, 2015).

The adoption of the Paris Agreement in December 2015 by 195 countries, including Canada, signalled a world shift in attitude towards climate change (COP21, 2015). To meet its obligations under the Paris Agreement, Canada has to set and meet more ambitious, science-driven emission reduction targets. As noted by Prime Minister Trudeau, *"we agreed to strengthen the global response to limit global average temperature rise to well below 2 degrees Celsius as well as pursue efforts to limit the increase to 1.5 degrees"* (Trudeau, 2015). The Prime Minister also highlighted the need to work with the provinces *"to meet our international commitments in tackling climate change and transitioning to a low carbon economy"*. It is unclear what more ambitious federal and provincial emissions targets will mean for new oil and gas development opportunities in Canada and in Newfoundland and Labrador.

Within the provincial government, the Climate Change Action Plan mandates the Office of Climate Change and Energy Efficiency (OCCEE) to *"advance sustained action on climate change and energy efficiency that effectively balances*

economic and environmental considerations, including deepening public awareness, understanding, and engagement" (OCCEE, n.d.). This mandate suggests that significant new resource developments could be evaluated through a climate change lens by the OCCEE in order to assess the trade-offs between the economic benefits of resource development and the associated climate change impacts, both positive and negative. In a submission to the Panel, the Assistant Deputy Minister noted that, to date, the OCCEE has not carried out any analysis of the GHG impact of potential hydraulic fracturing operations in Western Newfoundland (Janes, 2015). The lack of analysis was explained by the fact that there has been insufficient information made available by the *"local proponents that would allow for detailed analysis to occur within the local context"*.

In looking to the future, one should keep in mind that uses for oil extend beyond burning it as a fuel. Approximately 25% of the U.S. petroleum production in 2014 was used in non-fuel products, such as asphalt, plastics, and other synthetic materials, as well as in a variety of chemicals (USEIA, 2015). Oil is widely used to manufacture products that we use in our day-to-day lives. Western Canada and Newfoundland and Labrador derive significant economic benefit from production of "fossil carbons" (i.e., coal, oil, and natural gas), and *"we should look intensively for major new products based on fossil carbons that do not result in significant emissions of greenhouse gases and are functionally superior to and cost competitive with traditional products"* (Meisen, 2016).

Today, however, the majority of the oil that is produced, approximately 75%, is used as a fuel, and its primary GHG impact comes from its combustion. Overall, the GHG emissions from oil and gas are dominated by the consumptive factor with end users (i.e., industry, power generation, buildings, and transportation) accounting for 80-90% of the GHG emissions (OGCI, 2015). The remaining 10-20% of GHG emissions are from oil and gas operations.

6.3 Regional Economic Development Plans

A further element of public policy that needs to be considered in evaluating whether hydraulic fracturing should proceed in Western Newfoundland is economic development planning for the region. The Panel reviewed Strategic Economic Plans (SEP) for the Humber Economic Development Board (HEDB, 2009), the Marine and Mountains Zone Corporation (MMZC, 2011), the Nordic Economic Development Corporation (NEDC, 2011), the Long Range Economic Development Board (LREDB, 2011), and the RED Ochre Regional Board (REDORB, 2011).

As noted in a submission to the Panel by the Harris Centre at Memorial University:

> *"In the 1990s, the federal and provincial governments implemented the recommendations of the Task Force on Community Development, supporting Regional Economic Development Boards (REDBs) in 20 economic zones. REDBs had representation from business, labour, municipal government, education and training institutions, and other stakeholders"* (Harris, 2015a).

Of particular note is the suggestion that the REDBs would articulate *"a long-term vision for the zone, consistent with the values of the people of the zone"* (Harris, 2015a).

While the economic development plans developed by the REDBs are dated, they all identify tourism as a key economic driver for the future of their regions. Based on information submitted to the Panel by Hospitality Newfoundland and Labrador (HNL, 2015), the Western Destination Management Organization (WDMO, 2015), and the Gros Morne Cooperating Association (GM Cooperating, 2015), there appears to be a coordinated approach to the development of a tourism industry in the region, with Gros Morne National Park as the centerpiece.

The total number of visitors to Gros Morne National Park in 2015 was 207,000, an increase of 12.5% compared to 2014 and more than double the number of visitors to any other tourist destination in the province (NLBTCRD, 2016). The importance of Gros Morne National Park as an *"iconic tourism attractor"* is also highlighted in a recent study (Stoddart & Catano, 2015).

In other submissions to the Panel, a number of individuals, communities, and groups, including tourism operators in the Gros Morne area, highlight concerns about perceptions in the international market concerning unconventional oil and gas development in Western Newfoundland. In particular, they highlight concerns that "fracking" will impact negatively on tourism in the region, and particularly around Gros Morne (GM Adventures, 2015) (Neddies, 2015) (GM Coastal, 2015) (Woody Point, 2015) (Roost, 2015) (CBRHRC, 2015). A potential positive impact on the hospitality sector of a growing oil and gas industry in Western Newfoundland is noted in submission to the Panel from a bed and breakfast operator on the Port au Port Peninsula (Fenwick, 2015).

Annual tourism revenues in the province are in excess of $1 billion, with annual expenditures by non-resident visitors estimated to be $492.8 million (NLBTCRD, 2016). Accommodation occupancy rates (NLBTCRD, 2014) were used to estimate annual tourist expenditures of $176.4 million for Western Newfoundland (NLHFRP, 2016c). There are approximately 716 full-time equivalent jobs in Western Newfoundland for every $100 million of tourism expenditure in the region (EcoTec, 2016). For expenditures of $176.4 million, a total of 1,263 full-time equivalent jobs is estimated for Western Newfoundland. Any impact of unconventional oil and gas development on tourism in Western Newfoundland will have an effect on employment in the region.

In addition to tourism, agriculture and forestry also are noted as priority areas in most of the Strategic Economic Plans reviewed by the Panel. The importance of the fishing industry to Western Newfoundland is highlighted in a number of submissions to the Panel (CBRHRC, 2015) (GM Coastal, 2015) (PPBFC, 2015) (SOSS, 2015). Interestingly, conventional oil and gas exploration and production activity is identified in the plan for the Long Range Economic Development Board (LREDB, 2011), an area that encompasses the Port au Port Peninsula and Stephenville. Furthermore, oil and gas development is identified as a priority focus for the RED Ochre Regional Board (REDORB, 2011), an area that extends from Trout River in the south to St. Barbe in the north.

While the draft economic development plan for the Long Range Economic Development Board (LREDB, 2011) indicates that there has been conventional oil and gas exploration and production activity in the region, there is limited discussion of oil and gas as economic drivers in the region for the future. The area of "coastal and marine" is highlighted in the context of leveraging infrastructure in the region, but tensions were noted between traditional activity in coastal fisheries and agriculture and newer industries that also utilize coastal resources.

From a regional economic planning perspective, it is important to note that all of the plans available to the Panel predate consideration of unconventional oil and gas development in Western Newfoundland.

7 THE COMMUNITY CONTEXT FOR UNCONVENTIONAL OIL AND GAS DEVELOPMENT OF THE GREEN POINT SHALE

In evaluating the potential benefits and costs of unconventional oil and gas development in Western Newfoundland, the community context within which development is anticipated to take place needs to be examined. As illustrated in Section 9, for a development scenario based on the Green Point shale resource, most of the local impacts from such development are expected to occur within the Port au Port Peninsula and Stephenville areas.

Of the four public consultation sessions, the session at Port au Port East conveyed the strongest sense of culture and community. The presentations at this session included spoken word, music and song, and visual art. The people communicated a strong sense of place, rooted in the connection to past generations and a genuine concern for ensuring the quality of life and the environment for generations to come.

A history of Port au Port (Anonymous, n.d.) is available on the Town of Port au Port East website (PaP, n.d.). It appears that this document was written in the late 1960s. Circa 1935, in addition to fishing, employment on the Port au Port Peninsula included work at a limestone quarry on the south side of the Port au Port Peninsula at Aguathuna. The history of Port au Port states:

"Aguathuna was still providing jobs but this was the only employment besides fishing where a man could make his living."

The number of men working at the quarry in 1940 was reported to be 187. The limestone quarry continues to operate today, and a recent proposal for expansion of the quarry by the current owners, Atlantic Minerals Limited, indicates that the total number of employees is 138, with the majority of these people coming from around the Port au Port Peninsula (AML, 2015).

Construction of the Harmon Air Force Base began in Stephenville in 1941 and generated significant employment so that *"more than 1,500 Newfoundlanders quickly found work as tinsmiths, sheet metal workers, construction laborers, and carpenters"* (NL Heritage, 2006a). In its day, this provided considerable employment for people on the Port au Port Peninsula. The base operated until 1966.

Another major industrial employer in the region during the latter part of the 20th century was the linerboard mill, which was subsequently converted to a paper mill, in Stephenville. The Stephenville mill operated in various forms between 1973 and 2005 and provided employment for between 250 and 1600 people at different points in its history (NL Heritage, 2006b).

To understand the current socio-economic situation in this area, the Panel analyzed data available through the Community Accounts database (NLCA, 2016). The analysis focussed on Western Newfoundland, specifically Local Areas 36, 37, 38, 39, 40, and 70 in the Community Account database. Special attention was given to Local Area 37, which includes the communities of Black Duck, Cold Brook, Fox Island River-Point au Mal, Gallants, Georges Lake, Kippens, Mattis Point, Noels Pond, Port au Port East, Spruce Brook, Stephenville, Stephenville Crossing, and the Port au Port Peninsula. For the purpose of this report, this local impact area is referred to as either the Stephenville-Port au Port local area or Local Area 37.

A more complete discussion of the economic and employment data from the Community Accounts for Western Newfoundland is included in Appendix E (Locke, 2016), a report prepared by Dr. Wade Locke, a member of the Panel. Additionally, Dr. Kevin Keough, another member of the Panel, completed a review of the Community Accounts from the perspective of the region's health status. This review (Keough, 2016) is included as Appendix F of this report.

The remainder of this section draws on the key elements of Appendix E and Appendix F to help define a context for considering the potential socio-economic and public health impacts of unconventional oil and gas development within the Stephenville-Port au Port local area.

7.1 Demographic Context

As noted in Appendix E, *"a region's economic wellbeing and its overall sustainability are reflected by its demographic profile and how its demographic composition has changed over time"* (Locke, 2016). Within Western Newfoundland, the Community Accounts data shows that, with the exception of the Corner Brook-Pasadena local area (Local Area 39), population has been declining. For the Stephenville-Port au Port local area, the population declined by 15.1% between 1996 and 2011.

One contributing factor to the population decline in the Stephenville-Port au Port local area is the fact that deaths have now exceeded births in the region. Appendix E documents that *"there were 180 deaths in Stephenville-Port au Port and there were 120 births in 2013"*. Additionally, while the province as a whole experienced a positive (0.17%) net migration in 2013 , the Stephenville-Port au Port local area continued to experience a negative net migration during the same year. In short, for the Stephenville-Port au Port local area *"population has been in decline, while Newfoundland and Labrador's population has been growing in recent years"* (Locke, 2016). Taken together, this implies that the current population level in the Stephenville-Port au Port local area is not sustainable.

Another important demographic consideration is the local area's age dependency, which is defined as the ratio of the number of people over the age of 65 to the number of people between the ages of 15 and 64. An increase in age dependency over time within a region indicates an aging population base. For the Stephenville-Port au Port local area, the age dependency increased by 178% between 1996 and 2011. It is interesting to note that in 1996, the age dependency for the Stephenville-Port au Port local area was lower than for the province as a whole, while the age dependency in 2011 was significantly higher than for the province. Referring to Appendix E, the aging population in the region *"is an indicator of the [lack of] capacity to absorb new economic development or the need to have economic opportunities created by hydraulic fracturing in western Newfoundland"* (Locke, 2016).

Youth retention in Western Newfoundland is significantly lower than for the province as a whole. For instance, youth retention in the Stephenville-Port au Port local area is more than 25% lower than that experienced for the province as a whole. Although low youth retention may be a result of limited economic opportunities in a region, it also inhibits the ability for a region to respond to opportunities for local employment arising from any new industry that may be established within the region.

7.2 Income And Wellbeing Context

Employment and Social Development Canada reports that the wellbeing of individuals is *"associated with quality of life and influenced by factors such as family relationships, health, friends and community, and work"* (ESDC, 2016a). In particular:

> *"The family serves as a basic economic unit, with members providing support to one another. The level of after-tax income of family members determines whether families have sufficient resources to purchase the goods and services needed for well-being"* (ESDC, 2016a).

As discussed in Appendix E, income-related indicators of wellbeing for people living in a region include median family income, prevalence of low-income individuals, and prevalence of income support assistance (Locke, 2016).

While the Corner Brook-Pasadena local area has per capita personal income that is 96% of the provincial average, the Stephenville-Port au Port local area has a significantly lower per capita personal income, at approximately 80% of the provincial average. When taxes and transfers from government are taken into account, the per capita disposable income in the Stephenville-Port au Port local area increases slightly to approximately 83% of the provincial average.

The median family income for the Stephenville-Port au Port local area is 73% of the provincial average. Considering the prevalence of low-income individuals and the prevalence of income support assistance, the Stephenville-Port au Port local area is in a relatively poorer position compared with the rest of the province. The prevalence of low-income individuals for the Stephenville-Port au Port local area is approximately 50% higher than for the province. The Stephenville-Port au Port local area is significantly more dependent on income supports from government. For example, the prevalence of income support assistance in the Stephenville-Port au Port local area is approximately 100% higher than for the rest of the province.

7.3 Labour Market Context

The Panel also analyzed labour market statistics as indicators of both the need for additional employment opportunities within the region and the capacity of the region to take advantage of employment opportunities. As discussed in Appendix E, with the exception of the Corner Brook-Pasadena local area, *"the unemployment rates in Western Newfoundland are consistently higher than the provincial average"* (Locke, 2016).

For the Stephenville-Port au Port local area, in 2011 the unemployment rate, defined as the proportion of the labour force that is not currently employed but is actively looking for a job, was 18.8% compared with 14.6% for the province

as a whole. During the same year, the employment rate, which is defined as the proportion of the working age population that is employed, for the Stephenville-Port au Port local area was 37.5%, which is significantly lower than the provincial average of 50.7%.

Finally, the Panel considered the participation rate, which is defined as the proportion of the working age population that is employed or looking for employment (i.e., participating in the labour force). Again, with the exception of the Corner Brook-Pasadena local area, Western Newfoundland has a significantly lower participation rate than the province as a whole. In 2011, the Stephenville-Port au Port local area had a participation rate of 46.1% compared to 59.4% for the entire province.

Taken together, the low employment and participation rates, coupled with the high unemployment rate for Western Newfoundland, in general, and the Stephenville-Port au Port local area, in particular, highlight the need for economic development and employment opportunities within the region.

7.4 Health Context

Based on a review of the Community Account data for the Stephenville-Port au Port local area (NLCA, 2016), *"only 53% of the people in the local area rate themselves as having excellent or very good overall health status and about 20% rank themselves as having quite a bit of extreme life stress"* (Keough, 2016). This places the Stephenville-Port au Port local area among the lower self-assessed health status levels within the province. As discussed in more detail in Appendix F (Keough, 2016) and Appendix G (May & May, 2015), one of the determinants of health status for individuals is family income.

The Community Accounts data discussed in Appendix G does not show any significant differences between the Stephenville-Port au Port local area and the rest of the province in terms of the incidences of the more common illnesses among the population (May & May, 2015). As stated in Appendix F:

> *"In a few cases the incidences appear to be low, which might reflect special population characteristics, or they might just be due to random measurement effects in small populations over short time frames. The latter influence seems more likely"* (Keough, 2016).

In addition, the use of hospital resources for treatment of various conditions is not substantially different for the Stephenville-Port au Port local area compared with the usage for other parts of the province.

While health is a factor in wellbeing (ESDC, 2016a), the discussion of the Community Accounts in Appendix F describes that, for the Stephenville-Port au Port local area, *"93% of people indicate that they are very satisfied or satisfied with life in general, placing local area 37 in the 10th highest position among all local areas with respect to the population's sense of well-being"* (Keough, 2016). On this divergence between the self-assessed wellbeing and self-assessed health status, Appendix F states:

> *"The fairly high sense of well-being in the population might be positively influenced by state-supported income supplementation, and access to some benefits of a rural or semi-rural environment that allow for supplementation of income plus positive social and family factors not measured readily by the indicators"* (Keough, 2016).

7.5 Contextual Summary

In view of current challenges facing the Stephenville-Port au Port local area, it is interesting to reflect on the final paragraph of a History of Port au Port, written approximately 50 years ago, which reads:

> *"Now that construction on the base has ceased and unemployment has reached a state where over 500 families in the district of Port au Port are receiving Government relief, something must be done to get the people back to their basic industries which were neglected when Ernest Harmon Air Force Base made good jobs available. Young people have left and are still leaving for places where work is more plentiful, especially Toronto and Labrador. The utilization of resources, especially minerals and fisheries, are easily capable of maintaining employment and prosperity, not only in the Port au Port Peninsula but throughout all Western Newfoundland and efforts are being made to attract the attention of those who can help develop these resources"* (Anonymous, n.d.).

Western Newfoundland, in general, and the Stephenville-Port au Port local area, in particular, continue to have demographic, income, and labour market challenges that could benefit from new economic opportunities. For this reason, it is important to give full and fair consideration to new possibilities for local employment and income, including those associated with unconventional oil and gas development. Not only would an oil and gas industry bring employment to the region, it would tend to attract younger workers and younger professionals leading to more sustainable demographics. Quoting from Appendix E, *"the income and employment opportunities should attract more people to the area, which, in turn, should help stabilize the population base and reduce the average age of the area"* (Locke, 2016).

As discussed in a submission by the Greater Corner Brook Board of Trade, such new opportunities must be considered in view of criteria for *"responsible economic development"* which include (1) leads to diversification of the economy, (2) balances risks and rewards, (3) builds capacity, and (4) meets or exceeds Government regulations (GCBBT, 2015). Support for the need for economic development in the region from oil and gas development is also reflected in the public opinion survey carried out by MQO Research, which states:

> *"Specifically, the vast majority agree that Western Newfoundland needs the jobs and revenues from the industry (73%) and that the industry will create long-term benefits for Western Newfoundland (70%)"* (MQO, 2015).

If the health, social, and environmental risks of unconventional oil and gas development can be appropriately managed, as outlined in Appendix F (Keough, 2016) and Appendix G (May & May, 2015), there is the prospect of improved health outcomes as a result of the health benefits that may accrue through increased family income.

While economic activity, employment, and income are certainly important contributory factors to health status and wellbeing, they are not the only factors. Other contributory factors to health status and wellbeing include family life, social participation, leisure, and environment (ESDC, 2016a). While it is beyond the scope of the Panel's work to assess fully how these factors contribute to wellbeing in the region, there is reason to believe that these factors are strong in Western Newfoundland. The region's self-assessment of wellbeing, as recorded in the Community Accounts database (NLCA, 2016) and discussed in Appendix F, is among the highest in the province.

The potential negative impacts of full-scale hydraulic fracturing operations on the quality of life of individuals living in the vicinity of such operations must be examined. A recent review for the British Columbia Oil and Gas Commission (BCOGC) of British Columbia's hydraulic fracturing regulatory framework reports that *"disturbances to quality of life are a potential emerging issue, and [the Commission] is considering opportunities to better protect against those issues as activity in the region increases"* (BCOGC, 2015). In particular, the BCOGC notes:

> *"The area surrounding a large, multi-well pad undergoing multi-stage hydraulic fracturing may experience an increase in light, noise, air pollution, and area traffic that could be sustained over many months. For well-pads located near populated areas, these issues could lead to significant disturbances to the local population"* (BCOGC, 2015).

Many submissions to the Panel highlighted similar concerns about negative impacts of unconventional oil and gas developments on the quality and way of life in the communities adjacent to these developments.

As discussed by Employment and Social Development Canada:

> *"Generally, a strong sense of belonging is positively associated with better self-reported physical and mental health. A strong sense of belonging also contributes to individual and community well-being"* (ESDC, 2016b).

Visits to Western Newfoundland impressed upon the Panel that, notwithstanding the economic challenges that the region faces and which the review (Locke, 2016) of Community Account data illustrates, people in the region who chose to provide input to the Panel generally appear to have a strong sense of belonging to the region, are content with their current quality and way of life, and do not want to see that disappear or be negatively impacted as a result of industrial development.

Moreover, this sentiment was also conveyed to the Panel by the small number of community and municipal leaders who provided input to the Panel on behalf of their groups or municipalities. As noted in a submission to the Panel by the Qalipu Mi'Kmaq First Nation Band :

> *"The environment is paramount in the list of concerns for us. Contrary to some western ideologies, we are a part of (not separate from) the environment and it is a part of us as a people, in our lifestyles and our culture. The preservation of our lifestyle, culture, and hence environment is of utmost importance"* (Qalipu, 2016).

8 THE GEOLOGICAL CONTEXT FOR UNCONVENTIONAL OIL AND GAS DEVELOPMENT OF THE GREEN POINT SHALE

The Panel engaged the expertise of individuals with specific geoscience knowledge, including expertise in the geology of Western Newfoundland, to bolster the Panel's understanding of the relevant geoscience and its implications for the Panel's recommendations. Specifically, the Panel commissioned Dr. Elliot Burden, Professor of Earth Science at Memorial University, to prepare a report (Burden, 2016), which is included as Appendix J, reviewing the geological risks associated with unconventional oil and gas development in Western Newfoundland. The Panel also commissioned Dr. David Eaton, Professor and NSERC/Chevron Industrial Research Chair in Microseismic System Dynamics at the University of Calgary, and Dr. Edward Krebes, Professor of Seismology at the University of Calgary, to prepare a report (Eaton & Krebes, 2016), which is included as Appendix K, reviewing induced seismicity risks with specific consideration to hydraulic fracturing operations in Western Newfoundland.

The History of Petroleum Exploration in Western Newfoundland (Hicks & Owens, 2014) traces the use of petroleum resources from Western Newfoundland back to 1812 when oil seeping on the shoreline of Parson's Pond was used as a cure for rheumatism. Between 1867, when a well was drilled at Parson's Pond, and 1991, 64 wells are estimated to have been drilled. Since 1994, a further 40 onshore wells have been drilled in Western Newfoundland, resulting in one producing well at Garden Hill. In addition, there have been nine onshore-to-offshore conventional wells drilled in Western Newfoundland since 1995. Figure 16 illustrates the locations of the petroleum wells drilled in Western Newfoundland.

Of particular relevance to the work of the Panel is the Green Point formation as described in "The Green Point Report" (Hinchey, et al., 2014). Within this formation, the strata with high hydrocarbon potential are referred to as the Green Point shale. As reported in Appendix J, and in reference to other unconventional exploration plays in Western Newfoundland, *"quantifiable large volumes of rock with favourable organic geochemistry continue to remain elusive"* (Burden, 2016).

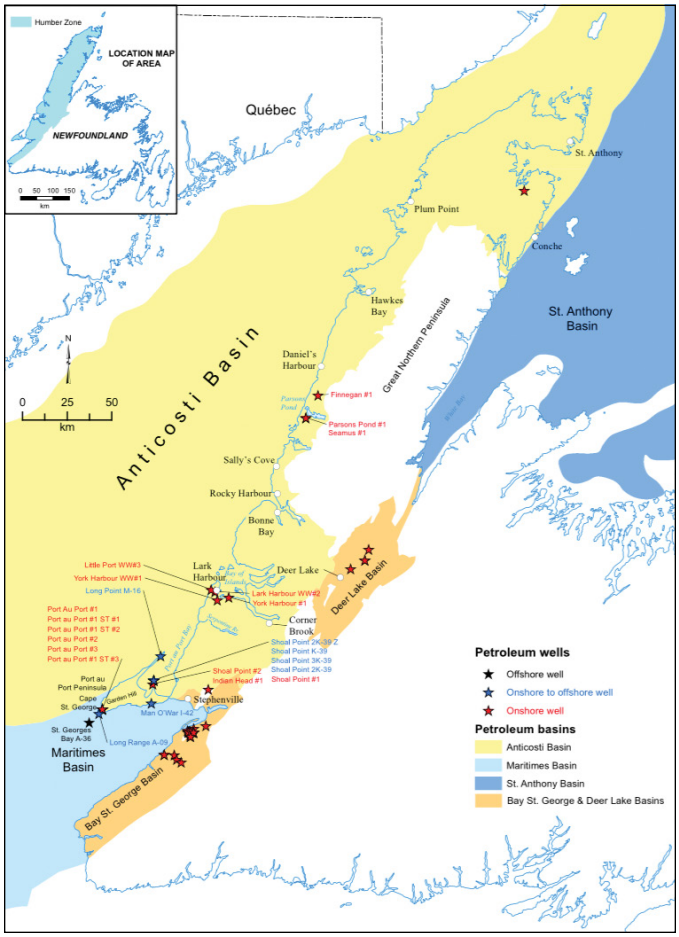


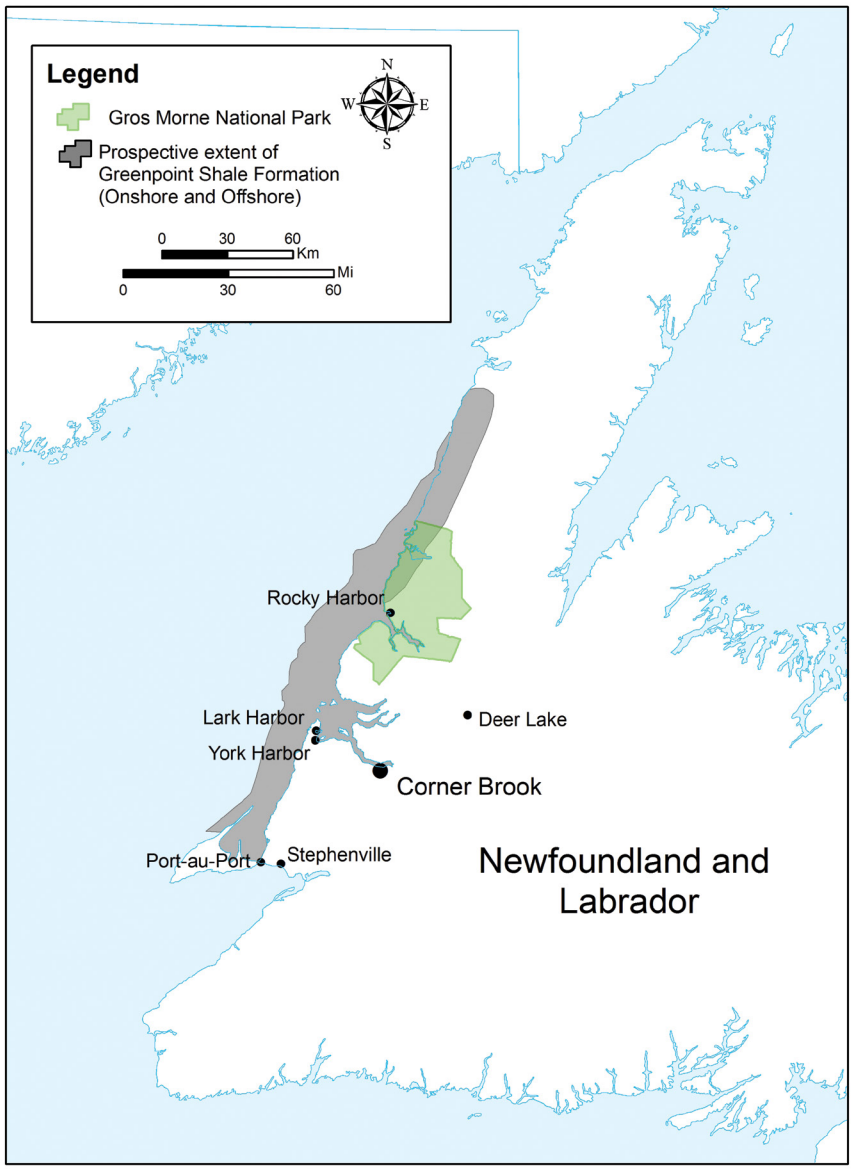
Figure 16. Locations of petroleum wells in Western Newfoundland (Hinchey, et al., 2014).

In considering the Western Newfoundland geological context for unconventional oil and gas development, the Panel focussed its attention on the opportunities and challenges of development of the Green Point shale. While there may be other opportunities to utilize hydraulic fracturing in developing other unconventional resources in Western Newfoundland, the Green Point shale was the only unconventional resource specifically highlighted in submissions to the Panel. Furthermore, it was the only resource for which a proponent (i.e., Shoal Point Energy) participated in the review process and expressed a need to utilize hydraulic fracturing in developing resources within its licence area. A commercial perspective on the Green Point shale is discussed on Shoal Point Energy's website (Shoal, 2013).

8.1 The Green Point Shale

Many of the health and environmental concerns about hydraulic fracturing operations in Western Newfoundland are elevated because of the complexity that has been reported about the underlying geology of the Green Point shale. Currently, however, it is difficult to quantify the health and environmental risks and to define appropriate mitigation approaches. There is a limited understanding of the geology and its implications for unconventional oil and gas development. Also, there is a lack of clarity with respect to how a full-scale development project may be carried out in the region. A full discussion of the complexity and limits in understanding of the Green Point shale geology is provided in the Green Point Report (Hinchey, et al., 2014).

Figure 17 illustrates the location of the prospective extent of the Green Point shale formation. The southern boundary of the prospective shale is offshore in the Port au Port Bay area. Outcrops of the prospective shale can be observed along the coastline at Green Point, located just north of Rocky Harbour in Gros Morne National Park. The prospective shale extends north as far as River of Ponds where the shale is onshore.



Data Sources: MorningStar N51-101 Compliant Report prepared for Shoal Point Energy and mapping prepared by Dept of Natural Resources which included the results of well evaluation conducted on Long Point M-16 and Shoal Point K-39 on the Port-au-Port Peninsula and well evaluation conducted on Seamus #1 and Finnegan #1 in the Parson's Pond area.

Figure 17. Location of the Green Point shale.

As noted in the Green Point Report, the Green Point shale is rich in organic carbon and contains oil that is *"either trapped in large-scale porosity features such as fractures, held in isolated small-scale pores, or adsorbed onto minerals or onto organic matter within the shale"* (Hinchey, et al., 2014). The Green Point shale is estimated to contain an average of 5.9% total organic carbon, and up to 10.4% total organic carbon in some areas.

As previously noted, the Green Point shale is described as a complex structure in comparison with other jurisdictions that have developed unconventional oil and gas resources. Quoting from the Green Point Report:

> *"The Marcellus, Bakken, and Barnett shales, like many other unconventional reservoirs in North America, are located in basins where the layers are deformed very little, in ways that are easy to map and understand"* (Hinchey, et al., 2014).

The Green Point shale does not have the typical layered sequences illustrated in Figure 3 in Section 2.1, and the Green Point Report goes on to say:

> *"The Green Point shale is not a simple package in a consistently layered sequence. The Green Point shale is part of an allochthon – a large slice of the Earth's crust that was pushed by colliding tectonic plates and moved along huge faults to a location far from its point of origin. As part of the allochthon, the Green Point shale has been folded, locally thrust over itself, thickened, or pinched out due to multiple tectonic events"* (Hinchey, et al., 2014).

With respect to understanding the geology of the Green Point shale, the Green Point Report states:

> *"Scientific understanding of the Green Point shale is incomplete. Due to a lack of sufficient modern geological data, it is difficult to accurately depict or predict the extent, location, rock characteristics, or shape of Green Point shale layers below the surface"* (Hinchey, et al., 2014).

There has been limited drill data collected for the Green Point shale, and seismic mapping of the Green Point shale has not been of sufficiently high quality to *"predict where the Green Point shale occurs at depth, how the composition of the Humber Arm Allochthon varies internally, and how it was affected by regional deformation and faulting"* (Hinchey, et al., 2014). This, in turn, reduces the understanding of the opportunities and challenges of exploitation of the Green Point shale resource.

Figure 18 illustrates the complexity of the geology of the Green Point shale. Given the current state of knowledge, the Green Point Report predicts that the Green Point shale is expected to contain *"highly contorted, folded, fractured, and faulted units."* It goes on to indicate that:

> *"The style of folding and faulting of the shale observed in outcrops onshore around Port au Port Bay is likely a good indication of the deformation that occurred at depth"* (Hinchey, et al., 2014).

Moreover, the Green Point Report emphasizes that, in the planning and design of well stimulation, there is a *"need to carefully assess and address this characteristic"*.

Figure 19 shows a cross section of the subsurface geology across Port au Port Bay for a line that includes a well near the tip of Long Point. The Green Point shale is part of the the Humber Arm Allochthon (i.e., green region). As illustrated in Figure 19, the Humber Arm Allochthon is a highly folded and distorted rock layer.

The Green Point Report highlights the need for additional data, both seismic imaging and physical core data, from the offshore component of the Green Point shale. Such data are important for understanding the structure of the shale, leading to more reliable predictions and more accurate risk assessments. The variation in structure across the Green Point shale is also noted, and the Green Point Report specifies that:

> *"Evaluating the amount and kind of deformation and fracturing at each proposed site will be an important part of the risk assessment for any hydrocarbon exploration of the Green Point shale. The greater the abundance of interconnected crosscutting fractures, the easier it is for hydrocarbons – or any fluid – to leak out of the formation"* (Hinchey, et al., 2014).

A modern 3-D seismic program would help to develop a basic understanding of the Green Point shale and to undertake the planning and evaluation of hydraulic fracturing operations, either exploratory or on a production scale. The Green Point Report suggests:

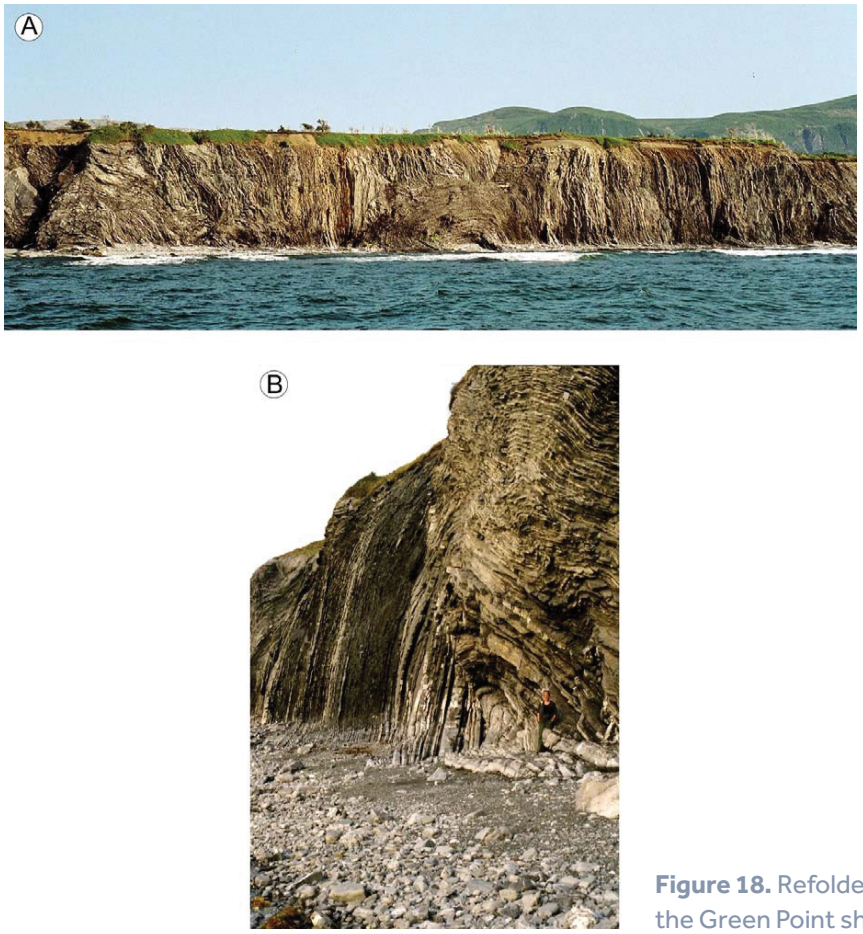


Figure 18. Refolded folds and faults along coastal outcrop of the Green Point shale (Burden, 2016).

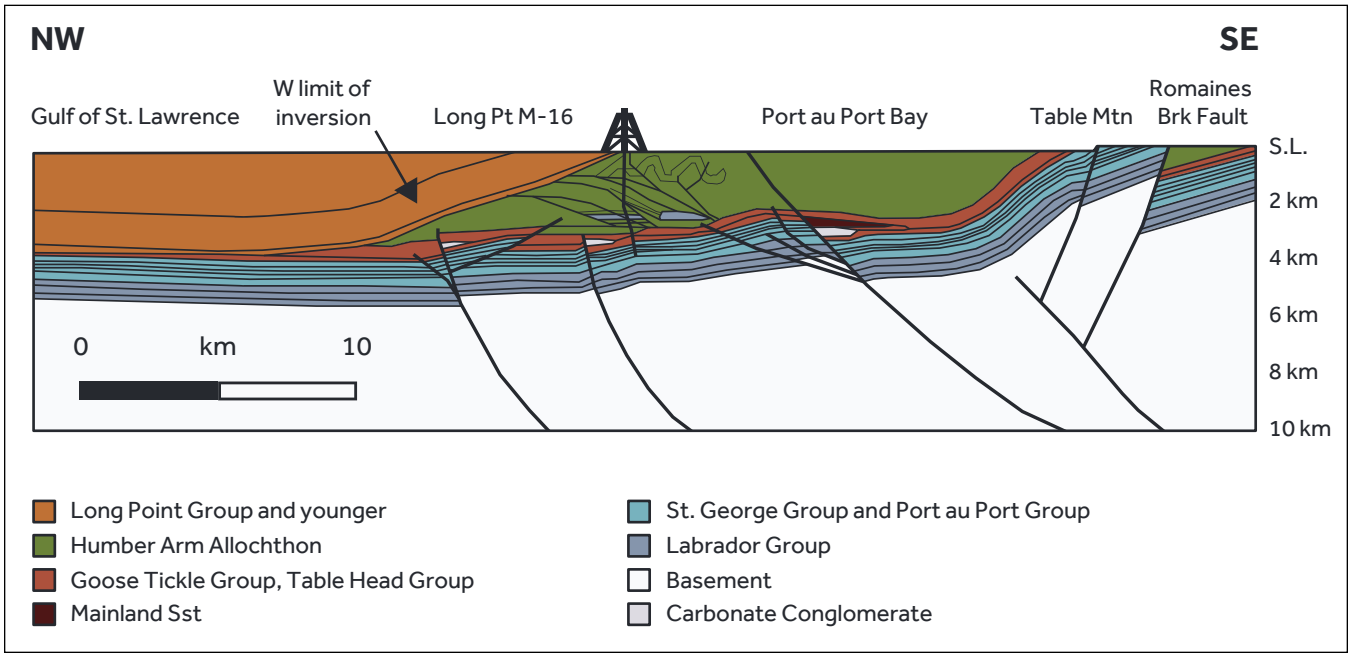


Figure 19. Cross section of subsurface geology across Port au Port Bay (Hinchey, et al., 2014).

> *"Because the available seismic data do not provide effective images of the Humber Arm Allochthon or the Green Point shale, a modern seismic program in the region would greatly improve the ability to predict where the Green Point shale occurs at depth, how the composition of the Humber Arm Allochthon varies internally, and how it was affected by regional deformation and faulting. Such higher quality data would also be crucial for designing – and predicting the effects of – an initial hydraulic fracturing program, as well as any future production operations"* (Hinchey, et al., 2014).

Insufficient high quality data from some of the prospective areas in the province is also noted in the Energy Plan, which reads:

> *"The existing data for our offshore and onshore areas have been acquired over a 50 year period using a variety of technologies. As a result, exploration companies have to develop regional geological models based on seismic data of varying age and quality. These models, therefore, may be incomplete and lacking fresh detail"* (NL Energy Plan, 2007).

In reference to a precondition to successful unconventional hydrocarbon development of the Green Point shale, Appendix J states that:

> *"There needs to be some proof that the complex geology we see on the surface disappears at depth, or that the multitude of fault and fracture we see on the surface can be successfully modeled and engineered under appropriate underground pressure and temperature to achieve a safe and sustained hydrocarbon flow"* (Burden, 2016).

The Green Point Report identifies a need for high quality data about the nature of the rock and the structure across the entire geological region where a development may take place. This is a prerequisite to industrial activity in the area. Appendix J also reinforces that:

> *"If unconventional hydrocarbon projects are to happen, at some point, subsurface testing of the integrity (leakiness) and interconnectedness of small and large faults will be required"* (Burden, 2016).

Some of the required information could be obtained initially through a small-scale stimulation program. Such a stimulation program would help develop the required understanding of local integrity and interconnectedness before carrying out the full-scale stimulation tests necessary to make economic decisions.

Another unknown for the Green Point shale is the integrity of the hydrostatic seal or caprock. Specifically, Appendix J emphasizes that:

> *"Ancient structural damage to the strata may become an issue if, by fracking, the older faults and fractures are opened up in an unacceptable manner and fluids are delivered to the surface"* (Burden, 2016).

While there is a history of oil and gas exploration in the Port au Port Bay area, there is low risk from the presence of legacy well bores since *"today's targets are apparently located offshore, and beyond the reach of older wells"* (Burden, 2016). Additionally, Burden (2016) states that the Green Point shale would not be at risk from unexpected overpressure of the reservoir.

Some insight into the strata of commercial interest is provided in a report by LGL Limited (LGL, 2013) to Shoal Point Energy. This report outlines a plan by Shoal Point Energy to undertake additional drilling from the existing Shoal Point well pad, and requests C-NLOPB approval for small-scale, near-wellbore stimulation of potential oil bearing strata at a depth of approximately 1,000 m. Information provided to the Panel by Shoal Point Energy (Shoal, 2015e) (Shoal,

2015f) (Morning Star, 2014) identifies the shale of greatest commercial interest is located toward the middle of Port au Port Bay, extending north-east from Shoal Point where the oil bearing shale is thought to be thicker and at a depth of 1,000-3,000 m. Information on Shoal Point Energy's website notes that *"thicker, undrilled parts of the basin may lie as deep as 5,000 m"* (Shoal, 2013). The website also notes that the oil in the Green Point shale is thought to be a light, sweet, and high quality crude oil.

8.2 Induced Seismicity

Seismicity is included as a topic within the Terms of Reference (NLDNR, 2014) for the Panel. The potential for hydraulic fracturing operations to induce earthquakes is an issue of growing public concern. This concern also featured prominently in the written public submissions to the Panel (Storey, 2015). Recent seismic events in Western Canada received considerable media coverage during the time when the Panel was carrying out its consultations.

Western Newfoundland is an area of low natural background seismicity (Eaton & Krebes, 2016). There have been only four seismic events recorded for the onshore region of Western Newfoundland in the last 16 years, based on monitoring by Earthquakes Canada's Canadian National Seismograph Network (CNSN). As illustrated in Figure 20, the most seismically active zone in this region is the Lower St. Lawrence Seismic Zone, located west of Anticosti Island.

Quoting from Appendix K:

> *"As a cautionary note, the sparse distribution of seismograph stations in this area implies that the magnitude of completeness (i.e. the magnitude level at which every earthquake is detected by the network, at a high level of confidence) is likely to be higher than areas where the station distribution is more dense"* (Eaton & Krebes, 2016).

In other words, for the current monitoring system, which includes a sparse distribution of seismograph stations, low magnitude events that occur at a distance from a seismograph station may not be detected, or be detectable, by the monitoring system. In the absence of additional data, the extent to which seismicity would be an issue for unconventional oil and gas development in Western Newfoundland is a matter of speculation.

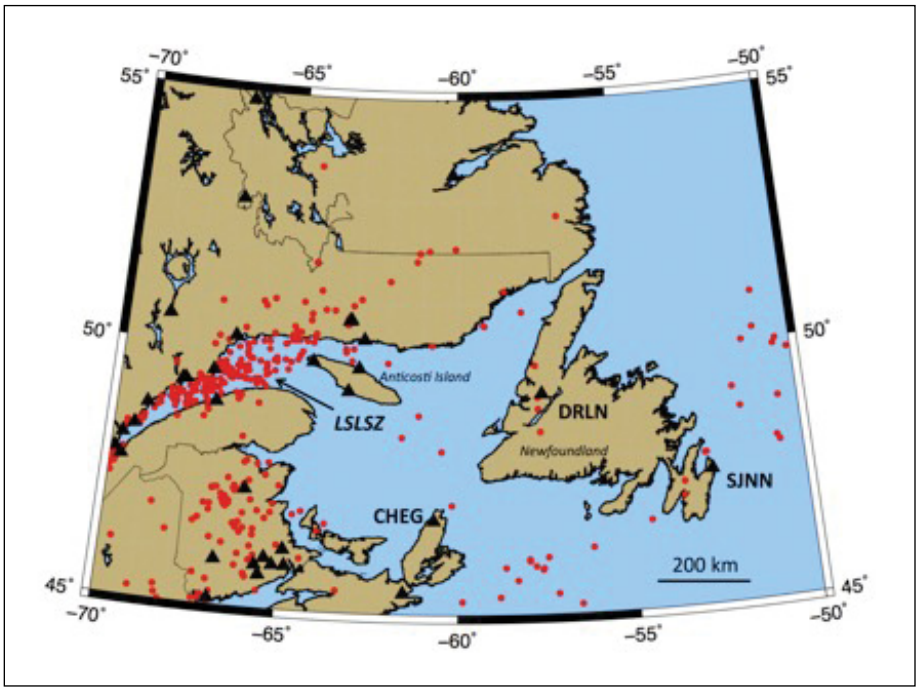


Figure 20. Seismicity map of Eastern Canada (Eaton & Krebes, 2016).

As discussed in more detail in Appendix K, induced seismicity refers to earthquakes or other seismic events resulting from human activities. The United States Geological Survey Earthquake Hazards Program website includes extensive information about induced seismicity (USGS, 2016). Induced seismicity *"occurs when there is a change in pore pressure or a change in stress, or both, near faults that are stable, but under critical stress"* (Jacobs, 2014).

Induced seismicity is not associated only with hydraulic fracturing operations. Concern about induced seismicity from enhanced geothermal energy systems, which are subsurface heat exchangers that extract heat that is naturally stored in underground rock, has delayed or suspended major projects (Majer, et al., 2007). Injection induced seismicity is also a concern for carbon capture and storage (CCS), which is used to reduce the emission of greenhouse gases by storing large quantities of carbon dioxide (CO_2) in large underground geological formations (Zoback & Gorelick, 2012). Since July 2013, there have been 75 seismicity events recorded at the Decatur CO_2 sequestration demonstration site (Kaven, et al., 2014).

The Intergovernmental Panel on Climate Change (IPCC) reports that *"the potential of CO_2 capture and storage is considerable, and the costs for mitigating climate change can be decreased compared to strategies where only other climate change mitigation options are considered"* (IPCC, 2005). With respect to underground geological storage of CO_2, the IPCC states that issues of induced seismicity, along with other risks, such as contamination of shallow aquifers from brine displaced from deep aquifers by injected CO_2, must be considered (IPCC, 2005). The IPCC concludes:

> *"Additional information on all of these topics would improve technologies and decrease uncertainties, but there appear to be no insurmountable technical barriers to an increased uptake of geological storage as a mitigation option"* (IPCC, 2005).

In the context of oil and gas development, induced seismicity had been primarily considered in the context of deep well disposal of produced water (i.e., water from oil and gas reservoirs that is a by-product of oil and gas production) from both conventional and unconventional oil and gas development (Rubinstein & Mahani, 2015). Seismic events triggered by fracturing a well were thought to be small and of low risk (Ellsworth, 2013). Ellsworth (2013) stated:

> *"There has been a growing realization that the principal seismic hazard from injection-induced earthquakes comes from those associated with disposal of wastewater into deep strata or basement formations".*

This thinking has more recently changed, and *"although wastewater disposal typically receives most attention, hydraulic fracturing is increasingly recognized as a significant source of seismic hazard"* (Atkinson, et al., 2015).

Induced seismicity during well stimulation arises from injecting fracturing fluids into a rock formation for the purpose of fracturing the rock. Additionally, the process of deep disposal of wastewater, which involves injecting flowback or produced water into an underground formation, may also result in induced seismicity. The fluid injection produces an increase in pore pressures in the formation, which can lead to increases in pore pressure along intersecting critically stressed faults. This can trigger an earthquake by causing a section of the fault to slip. Induced seismicity in Western Canada has increased in recent years. Further, there is evidence that this increased seismicity is a result of both hydraulic fracturing of multi-stage horizontal wells and deep well disposal of wastewater.

Following an investigation of seismicity in the Horn River Basin between 2009-2011, the British Columbia Oil and Gas Commission (BCOGC), in partnership with Geoscience BC and the Canadian Association of Petroleum Producers, added new seismograph stations in Northeastern British Columbia (BCOGC, 2012). This enhanced seismograph monitoring capacity was used to study seismic events in the Montney region between August 2013 and October 2014. The results of the Montney study (BCOGC, 2014a) indicated that of the 231 seismic events recorded during the study, 38 events were induced by deep well disposal of wastewater and 193 events were induced by well stimulation

using hydraulic fracturing. Areas with pre-existing stressed faults are thought to be particularly prone to induced seismicity (BCOGC, 2014a). It is important to recognize that, of the 231 seismic events recorded, only 11 were felt at the surface, and none of these caused any injuries, property damage, or loss of wellbore integrity.

As discussed by Maxwell (2013), well stimulation triggers microseismic events:

> *"Hydraulic fracture stimulation associated with creation of new fractures and interaction with pre-existing fractures results in small magnitude 'induced microseismicity'. The microseismicity is classified as induced in that it would not otherwise have occurred if not for the hydraulic fracture"* (Maxwell, 2013).

Maxwell (2013) refers to this as *"intentional 'induced microseismicity' that would not have occurred without the fracturing itself"*. As discussed in Appendix K, this type of seismicity is also known as *"operationally induced seismicity"*, which can be detected and monitored using microseismic monitoring techniques commonly used by the oil and gas industry to monitor hydraulic fracturing of oil and gas wells (Eaton & Krebes, 2016). These methods can also be used as a surveillance technology for monitoring and detecting fracture growth, including any propagation of fractures beyond the intended fractured zone for a well.

Anomalous induced seismicity (AIS) is *"seismicity that would not normally occur when performing hydraulic fracture completions"* (CAPP, 2012a). As discussed in Appendix K, AIS has higher magnitude levels than operationally induced microseismicity (Eaton & Krebes, 2016). These higher levels represent seismic activity, such as activation of a fault, that is not typically associated with hydraulic fracturing. Maxwell (2013) refers to this as *"unintentional 'triggered seismicity' resulting from the release of tectonic stress"*. To date, the highest-magnitude AIS event recorded in the Montney Trend occurred on August 18, 2015. Earthquakes Canada reported that this event measured M_L (local magnitude) 4.6.

In an Eastern Canadian context, induced seismicity has been studied in the Moncton sub-basin, which is located within New Brunswick (Lamontagne, et al., 2015). This study defined *"several characteristics of the seismicity of southeast New Brunswick where full-scale HF operations could eventually take place"*. As discussed in Appendix K, the study considered data collected from existing seismograph stations, coupled with the development of a new velocity model and with screening of the data to distinguish quarry blasts and road construction from natural or induced earthquakes. The study spanned a four-year period that included small-scale hydraulic fracture trials. The conclusion was that the one earthquake that was detected during the study was unrelated to well stimulation.

With respect to providing a diagnostic tool for induced seismicity, Lamontagne et al. (2015) states:

> *"To provide diagnostic evidence, we recommend that a microseismic array be established near HF [hydraulic fracturing] operations to monitor earthquake activity at close distances".*

The importance of seismic monitoring is also emphasized by Atkinson et al. (2015) :

> *"Our results highlight the importance of seismic monitoring in the immediate vicinity of fluid injection sites (both wastewater disposal and hydraulic fracturing) to accurately characterize injection-induced seismicity and ultimately mitigate the associated risk".*

Given that hydraulic fracturing operations, including well stimulation and deep well disposal, have caused induced seismicity in many jurisdictions, the Panel has no reason to believe that this would not be an issue for unconventional oil and gas development in Western Newfoundland.

Figure 21. Map of Port au Port Bay area (adapted from Google Maps).

8.3 Coastal Change around Port au Port Bay

Throughout the review, the Panel heard concerns related to long-term well integrity. The Panel's work also coincided with public expressions of concern about potential seepage from an abandoned oil well in the intertidal zone off the west side of Shoal Point. A preliminary investigation into the origin of the seepage was completed by Amec Foster Wheeler (Amec, 2015). The location of the oil seepage site is shown in Figure 21.

In the vicinity of the oil seepage off Shoal Point, there are three visible well casings in the intertidal zone which *"may be three of the original four to six wells drilled by the Western Oil Company around 1890, or they may be wells drilled by an unnamed English Company in the 1908 to 1911 period"* (Amec, 2015). The oil seepage is thought to be originating from a fourth well casing that is below the surface at the location of the leak. While drilling and completion technologies have advanced over the century since these wells were drilled, coastal changes also had significant impact over this same period. Consequently, due to erosion, the wells that were once onshore are now in the intertidal zone. As noted by Amec Foster Wheeler, these *"well casings have been damaged from being exposed to wind, wave, and ice pressures"* (Amec, 2015).

Coastal erosion was studied at 1,472 locations around Newfoundland (Catto, 2011). The study concluded that the Newfoundland coastline is subjected to coastal change arising from both short-term factors, such as storm events, and long-term factors, such as sea-level rise, landform type, and tidal range. A number of coastal locations around Port au Port Bay were included in the study, including Long Point. The significance of Long Point is that it is a likely location for well pads in a Green Point shale development scenario (Shoal, 2015a). For Long Point, the sensitivity to shorter term impacts is rated as extreme, with a Coastal Erosion Index of 24, while the sensitivity to longer term impacts is on the high end of moderate, with a Coastal Sensitivity Index of 23 (Catto, 2011). Long Point is fairly narrow, with a width less than 250 m for much of the distal part of the Point. Given this, it is reasonable to conclude that Long Point is prone to both short-term and long-term processes that could, over several hundred years, result in significant coastal change.

A submission to the Panel by the Geological Survey of Newfoundland and Labrador reported that *"the Geological Survey (of Newfoundland and Labrador) is monitoring rates of coastal change at over 110 sites across the Province"*, including sites around Port au Port Bay (NLGS, 2016). This coastal monitoring program has the objective of *"determining which areas are most vulnerable to erosions, flooding, and slope movement*", and serves as a basis to *"prioritize mitigation efforts and guide planning decisions"*. Similar concerns about coastal change are highlighted in Appendix J which states *"that while 20th century coastal erosion is relatively rapid, and older small scale infrastructure is affected 50 or 100 years later, 21st century change to coasts are predicted to occur at a much faster rate"* (Burden, 2016).

In terms of coastal monitoring around Port au Port Bay, an overview of five coastal monitoring sites (i.e., Winterhouse on Long Point, Shoal Point, Boswarlos, and two sites at Point au Mal) was provided to the Panel by the Geological Survey (NLGS, 2016). These sites are also highlighted in Figure 21.

From a coastal change perspective, both Winterhouse and the beach at Point au Mal are described as stable, while the cliff areas at Shoal Point, Boswarlos, and Point au Mal are prone to change and erosion. With respect to Shoal Point, the Geological Survey states :

> *"The cliff is eroding currently, as evident from the presence of slumps and gullying on the cliff face and observations suggest that erosion rates are higher than the provincial average. Historic rates of coastal erosion rates of unconsolidated cliffs in Newfoundland are up to 1 m per year, with an estimated average of 15 cm per year"* (NLGS, 2016).

Looking forward for Western Newfoundland, *"a potential sea-level rise of 80 to 100+ cm by 2099 is to be anticipated"* (Batterson & Liverman, 2010). As discussed in the submission to the Panel by the Geological Survey:

> *"Higher sea levels will increase the height of both extreme water levels and the high tide, resulting in heightened potential for coastal flooding further inland, and for increased erosion of the bases of cliffs"* (NLGS, 2016).

Climate change impacts on coastal change in Western Newfoundland are also important to consider (Finnis, 2013). An increase in temperatures in Newfoundland could lead to a decrease in the duration of sea ice cover in Port au Port Bay, leaving the shoreline more exposed to wind and wave erosion, as well as to larger storm surges.

9 AN ILLUSTRATIVE SCENARIO FOR UNCONVENTIONAL OIL AND GAS DEVELOPMENT OF THE GREEN POINT SHALE

To illustrate the scale of an unconventional oil and gas development project in Western Newfoundland and to help understand the potential benefits and costs, the Panel developed a full-scale scenario for an unconventional oil and gas development project in Western Newfoundland. Since the Green Point shale resource is the focus of current commercial interest, the Panel selected that resource as the basis for more detailed consideration. The illustrative scenario is based on the following:

- information provided by the Department of Natural Resources at the request of the Panel (NLDNR, 2015);
- knowledge in the public domain regarding exploration licence (EL) 1070 held by Shoal Point Energy, a company with an interest in using hydraulic fracturing to develop the Green Point shale resource (Morning Star, 2014);
- information submitted to the Panel by Shoal Point Energy (Shoal, 2015a);
- publicly available information about oil production from the Bakken formation in North Dakota, Montana, and Saskatchewan; and
- information from the Newfoundland and Labrador Community Accounts.

It is important to emphasize that the scenario developed by the Panel is not Shoal Point Energy's development plan. Rather, the scenario should only be considered as illustrative of the general nature and scale of full-scale development of the Green Point shale from onshore-to-offshore wells in the Port au Port Bay area. As such, the scenario provided a context in which the Panel could consider some of the socio-economic and technical issues related to unconventional oil and gas development in Western Newfoundland.

As discussed in more detail in Appendix D, gaining an understanding of the nature of typical unconventional oil and gas development methods that might be employed in Western Newfoundland *"would be part of a broad assessment of the socio-economic and environmental feasibility of going forward to establish a development plan"* (Dusseault, 2016). At this stage, it is not possible to be more precise about subsurface development details. Technology is evolving rapidly and horizontal well sections are being drilled at greater lengths. Drilling times are also decreasing, leading to construction cost reductions, and extended reach drilling is allowing horizontal wells to be drilled at greater distances from the well pad.

Hydraulic fracturing technologies are also changing and becoming more efficient. Details pertaining to optimal well orientation, lateral spacing between wells, fracture stage spacing along the length of the well, and treatment volume per stage can only be decided once additional geoscience and engineering data become available through exploration and technology trials. These decisions require more precise seismic surveys, stratigraphic drilling to assess the detailed geological nature of the potentially commercial development, assessment of the effectiveness of hydraulic fracturing, and initial production trials. Even then, modifications to the development plan will occur as additional information is collected. Notwithstanding these limitations, the scenario should allow for a better understanding of the issues that are critical to a decision about whether to grant permission for unconventional oil and gas development in Western Newfoundland.

As currently envisioned, if unconventional oil and gas development of the Green Point shale proceeds, there would first be an exploration phase involving drilling approximately 10-20 wells in different locations to assess the resource and to guide decisions whether to proceed to the larger-scale, commercial development phase. Typically, an exploration phase involves drilling one to four wells each year. During this exploration phase each well would be subjected to stimulation technology trials and temporary production tests to assess commercial potential and to develop a further understanding of how the Green Point shale responds to stimulation.

During an exploration phase, which may last several years, only one or two drilling rigs would likely be active. Furthermore, given the history of oil prices and improvements in technology, there may be significant changes

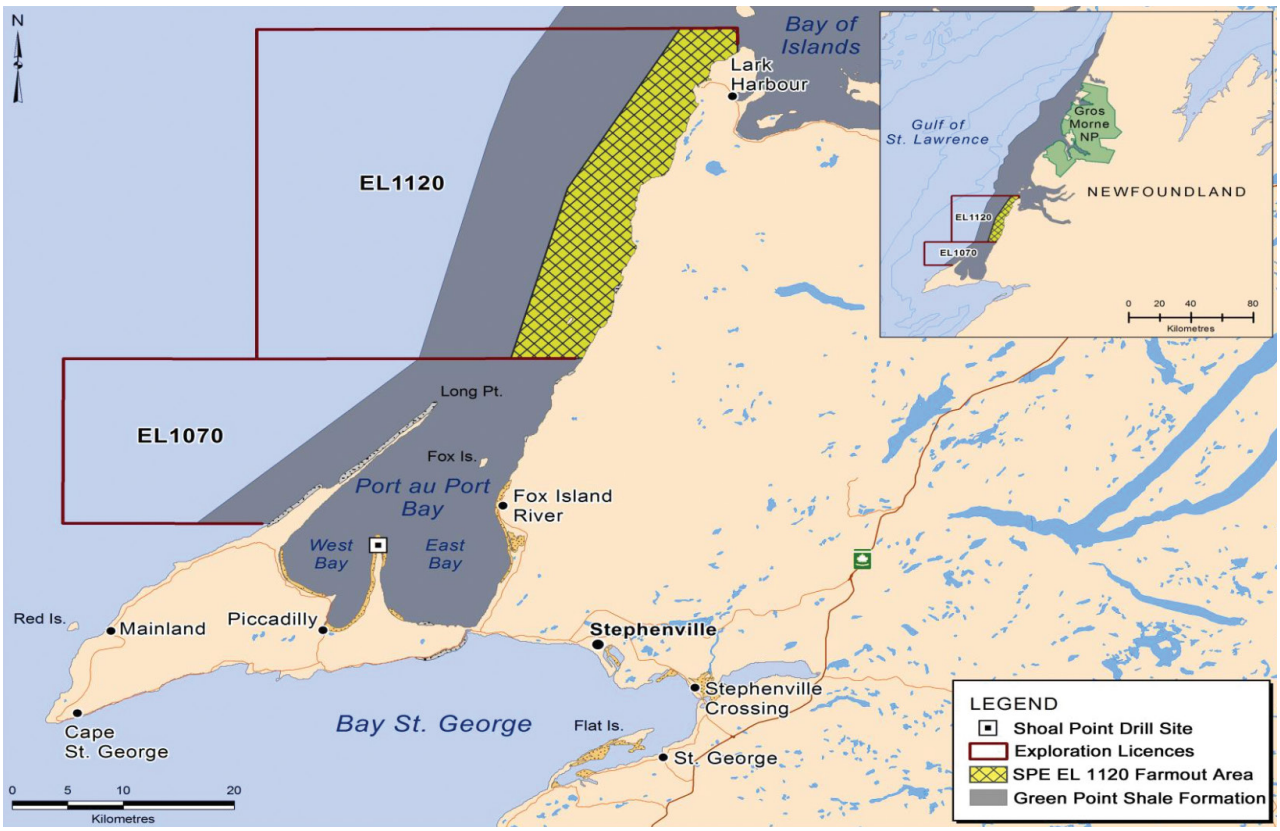


Figure 22. Licence areas associated with the Green Point shale (Shoal, 2015g).

in the industry assessments of commercial viability, such that exploratory drilling could be abandoned entirely or accelerated. In any case, at some point the exploration phase would be deemed to be complete, and development plans will either be abandoned or activated. In the latter case, the development plans will have been carefully established over a period of many years of exploration.

The scenario described in Section 9.2 illustrates the development and production phases of a project should a decision be made to proceed beyond the exploration phase.

9.1 Best Estimate for Prospective Resources

A summary of the work completed to date related to the Green Point shale is found in the Green Point Report (Hinchey, et al., 2014). Also, work done by Shoal Point Energy is discussed in the Morning Star Report (Morning Star, 2014), a report that includes the required disclosures from publically traded oil and gas companies. The Morning Star Report gives a *"best estimate"* for *"prospective resources"* to be 428 million barrels of oil (MM BBLS) for the EL 1070 licence and the Shoal Point Energy farm-in area within the EL 1120 licence. Figure 22 shows the locations of these licences.

As described in the Morning Star Report, the best estimate corresponds to an amount where it is:

> *"Equally likely that the actual remaining quantities recovered will be greater or less than the best estimate. If probabilistic methods are used, there should be at least a 50 percent probability (P50) that the quantities actually recovered will equal or exceed the best estimate"* (Morning Star, 2014).

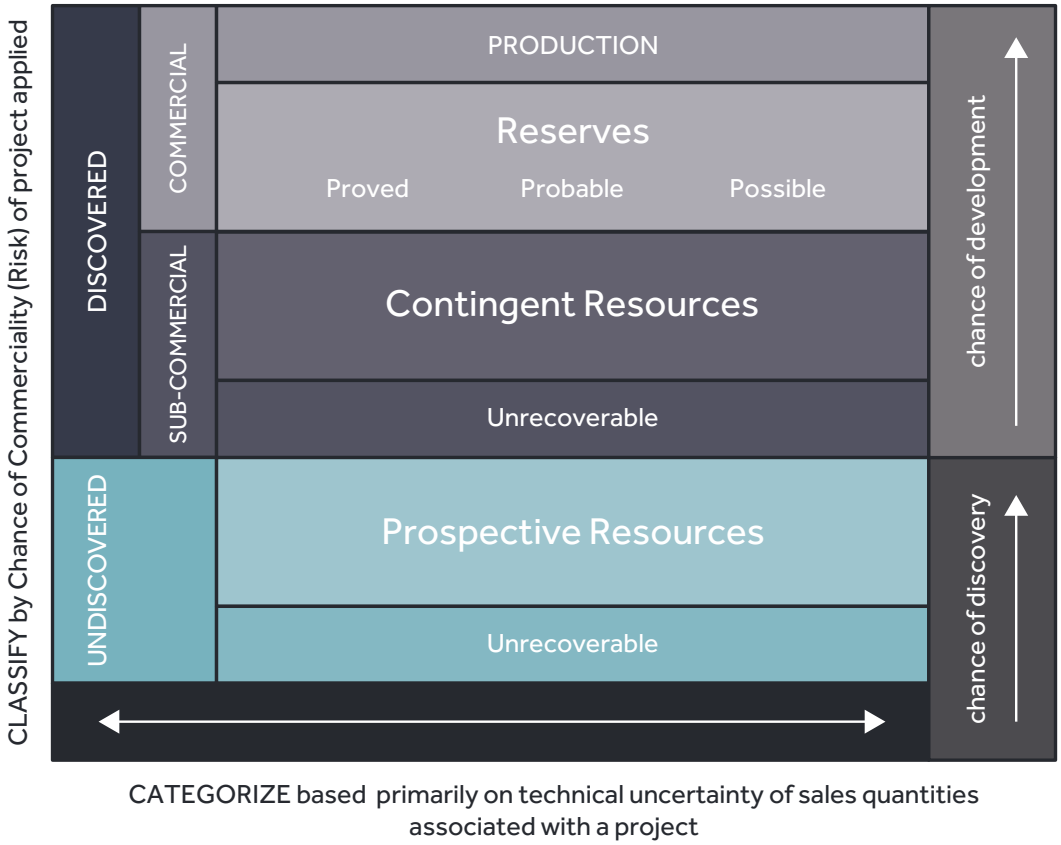


Figure 23. Society of Petroleum Engineers definitions of reserves and resources (SPE, 2007).

The prospective resources are defined in the Morning Star Report as:

> *"Those quantities of petroleum estimated, as of a given date, to be potentially recoverable from undiscovered accumulations by application of future development projects"* (Morning Star, 2014).

The Society of Petroleum Engineers recommended definitions of resources, reserves, and probabilities are shown in the Figure 23 (SPE, 2007).

To put the prospective resource estimates reported for Shoal Point Energy's licence areas into perspective, it is useful to consider that the current estimates of proven oil reserves for the existing conventional offshore projects are 1,644 million barrels for Hibernia, 528 million barrels for Terra Nova, and 305 million barrels for White Rose (CNLOPB, 2015). The Green Point shale resource appears, given what is known about the resource estimates, to be the basis for a project rather than for an unconventional oil and gas industry in Western Newfoundland.

The combined licence area for the best prospective resource estimate of 428 million barrels is approximately 820 km^2. This corresponds to approximately 522,000 barrels per km^2, assuming that the oil resource is uniformly distributed over the licence area. In practice there will be "sweet spots" within the licence areas where oil will be in greater concentrations than implied by the assumed uniform distribution, or will be be more easily extracted. Such detailed information, however, was not available to the Panel and may not be known with any degree of certainty until after further exploration work is completed.

9.2 An Illustrative Onshore-To-Offshore Development Project

For the purpose of gaining a better understanding of the costs and benefits of a potential development scenario, the Panel considered a hypothetical onshore-to-offshore project that includes 480 production wells, each including a 2-km-long, horizontal well section drilled under Port au Port Bay. The production wells would be drilled and completed from 30-40 onshore well pads, with 12-16 wells per pad. Each 2-km-long, horizontal well is assumed to drain along a length of 2.2 km, and wells are assumed to be spaced at 0.267 km. It is assumed that there will be sufficient drilling capacity to drill 80 wells per year. This implies that a total of six years will be required to drill and complete the 480 wells.

For this project, the 480 production wells would drain approximately 282 km^2, corresponding to a best estimate recovery of approximately 150 million barrels of oil. In order to put this volume of oil into perspective, 150 million barrels of oil represents approximately 3.5 years of refinery capacity at the North Atlantic Oil Refinery at Come-by-Chance, which can refine approximately 115,000 barrels of oil per day (NARL, 2006).

Depending on the local depth to the Green Point shale that is considered to be prospective for oil, as well as its thickness and the response of the shale to hydraulic fracturing, extended reach drilling may be used in the future to access parts of the Green Point shale that are farther offshore. With such an approach, which is beyond the scope of the initial development scenario, it is conceivable that each pad could have 25-30 wells draining a subsurface area of 15-18 km^2, depending on the lateral spacing required for good oil recovery. Furthermore, depending on the thickness of the Green Point shale and its response to stimulation, it is possible that multiple levels of horizontal wells could be used to develop the resource and this could result in a larger number of wells at each well pad.

Figure 24 shows a possible future arrangement of horizontal wells extending offshore from onshore well pads around Port au Port Bay that may facilitate recovery of a significant portion of the 428 million barrels of prospective resources. Here it is assumed that each horizontal well section is 2.5 km long and that there are also extended reach wells, providing a total reach of 5 km from the well pad. Such an arrangement could allow for complete coverage of the area of Port au Port Bay using onshore-to-offshore wells.

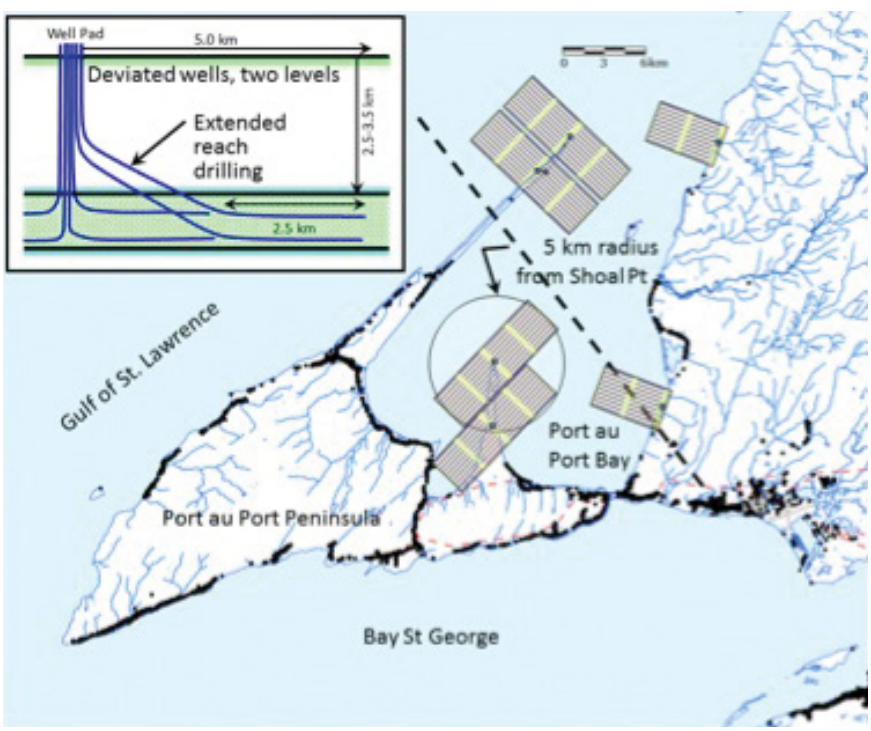


Figure 24. Illustration of onshore-to-offshore horizontal wells in Port au Port Bay (Dusseault, 2016).

Figure 25. Google Maps image of existing conventional oil well at Shoal Point.

At this time, however, speculation as to what might be an optimum development scheme to maximize the recovery is difficult since rapid technological progress will see more options available in the future. In addition, the concept of long horizontal wells is conducive to the "layer-cake" geology illustrated in Figure 3 and Figure 4 where a long horizontal well drains oil from a relatively continuous horizontal layer. If the target formation is highly contorted and folded, as suggested in the Green Point Report (Hinchey, et al., 2014), different development options would have to be evaluated.

As discussed in Section 5, each well pad corresponds to a cleared area of approximately 0.03 km^2 (i.e., 6-7 acres) during construction of the wells. Once construction of all wells on a pad is complete, and the wells are put into production, the footprint of the well pad could be reduced to an area of approximately 0.015 km2 (i.e., 3-4 acres). Since well pads would be connected by water, oil, and gas pipelines, rights-of-way with typical widths of 10-15 m would be constructed. As a point of comparison, Figure 25 shows the footprint for the existing site for the conventional oil well at Shoal Point on the Port au Port Peninsula. The cleared area toward the end of Shoal Point corresponds to an area approximately 0.01 km^2.

In addition to the 150 million barrels (bbls) of oil, 75 billion standard cubic feet (scf) of associated natural gas would be recoverable based on a gas/oil ratio of 500 scf/bbl estimated from test results available for the Shoal Point K-39 well (NLDNR, 2015). A summary of oil producing horizontal wells in the Middle Bakken formation was used to estimate a produced water/oil ratio of 0.77 (NDSG, 2015).

The average initial production per well would be 400 barrels of oil per day, with subsequent decline rates consistent with published horizontal well data from the Bakken formation (Cook, 2013). Each well would produce for 20 years. Figure 26 illustrates the production profile for the development scenario with the 150 million barrels of oil as the base case. As well, high and low estimates of 200 million barrels and 100 million barrels, respectively, were analyzed.

Each production well would use four million US gallons of make-up water (USGS, 2015) and 5000 US short tons of proppant (Bleiwas, 2015). Flowback is assumed to be 50% of the volume of the hydraulic fracturing fluid.

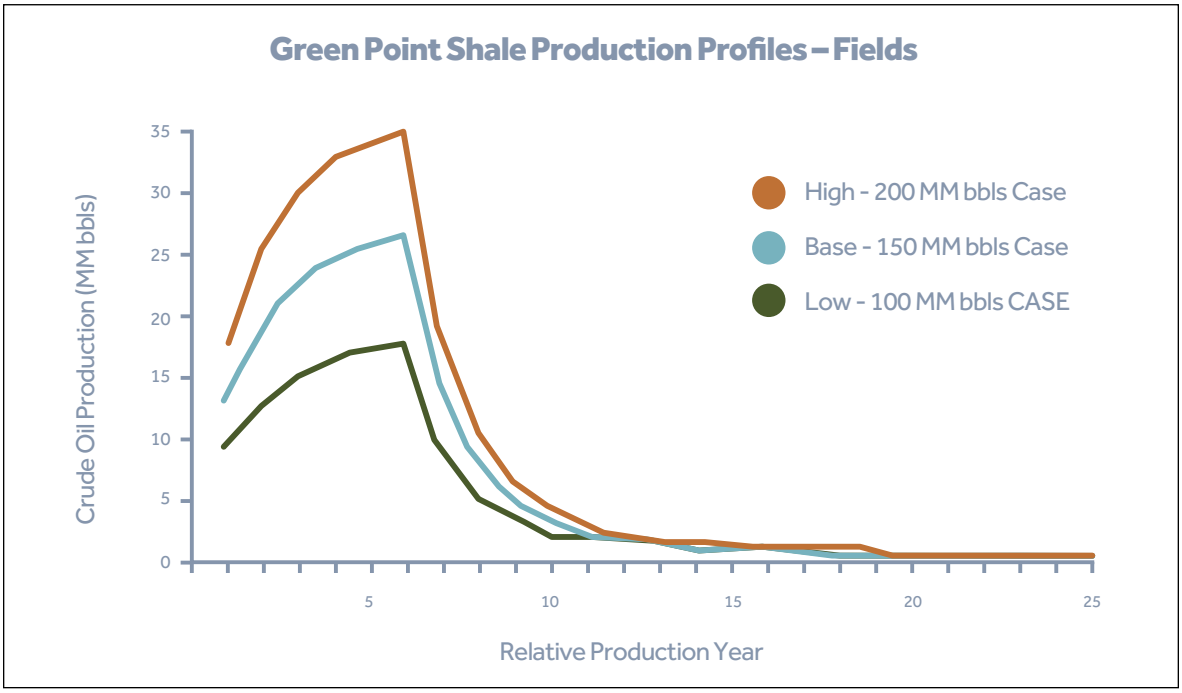


Figure 26. Green Point shale scenario production profiles (Rodgers, 2015).

There would also be a need to construct and operate central processing facilities, main gathering lines, central storage and loading facilities, and a marine terminal (NLDNR, 2015). In addition, field gathering lines and processing facilities at each pad would need to be constructed and connected to the wells. Again, for the purpose of this illustration, flowback and produced water transportation would utilize tanker trucks, while movement of oil would be via pipeline to a marine terminal for export to world markets (NLDNR, 2015).

In this illustrative scenario, the associated natural gas would be used to generate electricity, which would be necessary to run the production operations. Consequently, the project includes the construction and operation of a gas-to-electricity generating facility, gas flow lines, and an electricity distribution system. Any electricity produced in excess of the needs of the project would be placed into the regional grid.

Two options for handling flowback and produced water were considered. The first involves the construction and operation of eight deep disposal wells for wastewater reinjection, and the second involves the transportation and off-site treatment of the flowback and produced water. Finally, the project incorporates the costs of well decommissioning and abandonment.

9.3 Economic Feasibilty/Fiscal Analysis and Economic Input-Output Analysis

The Panel commissioned two reports, which are included as appendices to this report, to explore the economic viability of the illustrative project described above, the fiscal implications for the province, and the associated employment that is anticipated to flow from the project. Specifically, Appendix Q (Rodgers, 2015) reviews the economic and fiscal impacts of the project, while Appendix R (EcoTec, 2016) summarizes an economic input-output impact analysis. Although the full analyses of the economic, fiscal, and employment implications of the project are included in the appendices, the remainder of Section 9 highlights some of the key results from those analyses.

GREEN POINT SHALE ANALYSIS ASSUMPTIONS			
	Recoverable Reserves Case		
	Low	Base Case	High
Assumptions			
Estimated Recoverable Reserves (EUR) Oil	100 MM bbls	150 MM bbls	200 MM bbls
EUR per Well	208,333 bbls	312,500 bbls	414,667 bbls
Gas Oil Ratio (GOR)	Same as Base Case	500 scf/bbl	Same as Base Case
Price (USD $/bbl Brent)		$85/bbl	
Exchange Rate (USd $/CDN)		0.9	
Inflation Rate		2.0%	
Assumed Private Weighted Average Cost of Capital – Real		10.0%	
Assumed Private Weighted Average Cost of Capital – Nominal		12.2%	
Number of Wells		480	
Assumed Maximum Number of Wells Drilled per Year		80	
Assumed Well Life (Years)		20	
Number of Years for Drilling Production Wells		6	
Development Configuration – See Figure 9			
All facilities will be onland with wells drilled from onshore to offshore			
Cost Details - CapEx (CND $)			
Average cost per production well.	Same as Base Case	7,042,362.40	Same as Base Case
Total production well cost		3,380,333,950.00	
Water disposal wells (water injected)		74,400,000.00	
Central Processing Facilities & Main Gathering Lines		80,000,000.00	
Central Storage & Loading Facilities		120,000,000.00	
Field Oil & Gas Gathering Lines for 30 well-pad sites		34,285,714.29	
Field Oil & Gas Treatment Facilities		34,285,714.29	
Main Processed Gas Line		80,000,000.00	
Lease & Install 3.5 MW Gas to Electric Turbines		40,000,000.00	
Electricity Generation		40,000,000.00	
Marine Terminal		150,000,000.00	
Pre development		50,000,000.00	
Total CapEx - with Deep Well (DW-Inj)		**4,083,305,378.57**	
Total CapEx - with Off-Site Transport & Treatment (OSTT)		**4,027,505,378.57**	
Cost Details - OpEx (CND $)			
Field Oil Fixed Opex	40,000,000.00	60,000,000.00	80,000,000.00
Field Oil Variable Opex	60,000,000.00	90,000,000.00	120,000,000.00
Storage & Loading Facilities Opex	100,000,000.00	150,000,000.00	200,000,000.00
Well Operating Costs Fixed ($2,000/month)	230,400,000.00	230,400,000.00	230,400,000.00
Field Gas Fixed Cost	15,000,000.00	22,500,000.00	30,000,000.00
Field Gas Variable Cost	25,000,000.00	37,500,000.00	50,000,000.00
Electricity Distribution	25,000,000.00	25,000,000.00	25,000,000.00
Field Abandonment	48,000,000.00	48,000,000.00	48,000,000.00
Water Handling			
Transportation of water for hydraulic fracturing fluid (CDN $)	22,860,000.00	22,860,000.00	22,860,000.00
Produced water transportation to injection site (CDN $)	59,916,000.00	83,016,000.00	106,116,000.00
Deep-well injection cost (CDN $)	49,930,000.00	69,180,000.00	88,430,000.00

GREEN POINT SHALE ANALYSIS ASSUMPTIONS			
	Recoverable Reserves Case		
	Low	Base Case	High
Flowback & Produced Water Transport – with Deep Well (DW-Inj)	0.00	0.00	0.00
Flowback & Produced Water Transport – without Deep Well (DW-Inj)	2,496,500,002.00	3,459,000,004.00	4,421,500,005.00
Flowback & Produced Water Treatment – with Deep Well (DW-Inj)	0.00	0.00	0.00
Flowback & Produced Water Treatment – without Deep Well (DW-Inj)	299,580,000.00	415,080,000.00	530,580,001.00
Total Water Handling Costs - with Deep Well (DW-Inj)	**132,706,000.00**	**175,056,000.00**	**217,406,000.00**
Total Water Handling Costs - with Off-Site Transport & Treatment (OSTT)	**2,818,940,002.00**	**3,896,940,004.00**	**4,974,940,006.00**
Total OpEx - with Deep Well (DW-Inj)	**676,106,000.00**	**838,456,000.00**	**1,000,806,000.00**
Total OpEx - with Off-Site Transport & Treatment (OSTT)	**3,362,340,002.00**	**4,560,340,004.00**	**5,758,340,006.00**
Rodgers Oil & Gas Consulting with input from the Panel			

Figure 27. Economic analysis assumptions (Rodgers, 2015).

9.3.1 Analysis Assumptions

An economic and fiscal analysis was completed for a project designed to recover 150 million barrels of oil, which is based on the best estimate for oil recovery (Morning Star, 2014). The sensitivity of the results to production levels was evaluated by also assuming oil recovery at 100 million barrels and at 200 million barrels.

The Panel sought input from the Department of Natural Resources for estimates of the capital and operating costs for the 480-well development scenario (NLDNR, 2015). Figure 27 summarizes estimates of the capital expenditures (i.e., primarily the one-time costs for constructing the wells and associated infrastructure) and the operating expenditures (i.e., primarily the recurring costs when the wells are in production) assumed for the project.

The capital costs would be incurred over the initial six-year construction period, during which wells would be drilled and completed and the associated facilities would be constructed. Since each well would have a production lifetime of 20 years, and the wells would be developed over a six-year period, the operating expenditures for the project would be spread over the 26-year life of the project.

The average drilling and completion cost of each production well is estimated to be $7 million, assuming an initial cost of $10 million per well, a 15% reduction in cost for the first five years, and a further 1% reduction in cost for subsequent years to reflect savings due to increases in drilling efficiency.

Additionally, the capital cost of a new marine terminal is estimated to be $150 million; the capital cost of electricity generation and distribution is estimated to be $80 million; the capital cost for the field gathering lines, the treatment facilities, and the main processed gas line is estimated to be approximately $150 million; and the capital cost of the central gathering, processing, storage, and loading facilities would be $200 million. Predevelopment expenditures of $50 million cover exploration costs for activities such as seismic surveys and drilling of stratigraphic wells. Furthermore, the capital costs are assumed to be independent of production levels and are therefore fixed, while some operating costs are assumed to vary with production levels.

Based on the above estimates, the capital cost to drill and complete 480 wells and to put in place the associated infrastructure is just over $4 billion. The operating cost for the 150 million barrel project, using the option of deep well disposal of flow-back and produced water (i.e., wastewater), is approximately $840 million, which implies a total project cost of approximately $4.9 billion. The operating cost for the option using off-site transportation and treatment of flowback and produced water is approximately $4.6 billion, which implies a total project cost of approximately $8.6 billion.

9.3.2 Economic Feasibility/Fiscal Analysis

In evaluating a potential resource development project, both the economic and fiscal impacts must be considered (IPD, 2014). The feasibility/fiscal analysis considered the economic viability of the illustrative project and the anticipated fiscal impact on the province's revenues (Rodgers, 2015). It is important to note that, based on the current state of knowledge, there is considerable uncertainty associated with the illustrative scenario. Consequently, the economic and fiscal analyses must be read and interpreted with that uncertainty in mind.

The analysis was completed with the following additional assumptions and conditions:

- oil prices of $50 US per barrel, $85 US per barrel (base assumption), and $100 US per barrel;
- variations of -25% and +50% on the base case drilling costs;
- a $100 million capital expenditure by the proponent for new road construction, expended before the start of production;
- a socio-economic/environmental impact fee varying from 0% to 3% of provincial royalties to compensate local residents for potential negative socio-economic and environmental effects and to provide additional local benefits to the areas that are adjacent to the resource development;
- discount rates of 10% and 20% for net present value (NPV) calculations for the project;
- Canadian to United States dollar exchange rates of 0.80, 0.90 (base assumption), and 1.00;
- price and cost escalation equal to inflation at 2% per annum;
- transportation costs of $2.00 per barrel for transporting oil from the Stephenville-Port au Port area to world markets; and
- Newfoundland and Labrador offshore generic fiscal terms (i.e. royalty and profit share) apply to the development.

Figure 28 summarizes the project economics when off-site wastewater treatment is used, while Figure 29 summarizes the project economics when deep well disposal is used.

For the base case project (i.e., 150 million barrels recoverable, $85 US per barrel) with the off-site wastewater treatment option, the net present value (NPV) for the project using a 10% discount rate is $1,112 million, including $111 million to Nalcor Energy which, consistent with the province's energy plan, is assumed to have a 10% equity stake in the development. The provincial government revenue from corporate income tax, royalties, and profit sharing over the 26-year life of the project is $2,175 million, or $83.7 million per year, while the federal government revenue from corporate income tax is $631 million, or $24.3 million per year.

As suggested in the written submission to the Panel by the City of Corner Brook (Corner Brook, 2015), the analysis of the project includes local sharing of royalties. This is assumed to be a percentage of the royalty paid to the province, with the local amounts ranging from $8.4 million to $25.3 million depending on the royalty percentage (i.e., 1%, 2% or 3%) assumed. This corresponds to $324,000-$973,000 in local revenues annually over the life of the project. This does not preclude the province from investing some of its share of the total revenues in the region to facilitate the diversification of the local economy.

As illustrated in Figure 28, for the off-site wastewater treatment option, the net present value (NPV) calculations do not indicate that the project is viable at $50 US per barrel. The project, however, is viable for the other combinations of oil price and recoverable reserve estimate.

For the base case project (i.e., 150 million barrels recoverable, $85 US per barrel) with the deep well disposal of wastewater option, the net present value (NPV) for the project using a 10% discount rate is $2,261 million. This includes $226 million to Nalcor Energy as a 10% equity partner. The provincial government revenue from corporate

Figure 28 (see page 63). Summary of economic results for wastewater treatment option (Rodgers, 2015).

GREEN POINT SHALE ECONOMIC RESULTS Canadian Dollars – Real Value (Millions)									
Water Disposal – Offsite Transport & Treatment									
	Recoverable Reserves								
	100 MM bbls			**150 MM bbls**			**200 MM bbls**		
United States Dollar Price Per bbl	$50	$85	$100	$50	$85	$100	$50	$85	$100
Canadian Dollar Equivalent Price [1]	$53.56	$92.44	$109.11	$53.56	$92.44	$109.11	$53.56	$92.44	$109.11
Project									
Net Cash Flow (NCF)	-1,515.06	1,072.26	1,867.64	-567.52	2,742.33	3,981.26	355.05	4,468.19	6,098.78
Net Present Value (NPV10)	-1,620.48	7.36	546.18	-1,023.97	1,112.02	1,900.68	-441.65	2,205.60	3,225.60
Internal Rate of Return (IRR)	-14.93%	10.11%	18.35%	-5.49%	27.16%	39.44%	3.39%	44.00%	59.40%
Private Investor (Shoal Point Energy)									
Net Cash Flow (NCF)	-1,363.55	965.04	1,680.88	-510.77	2,468.09	3,583.13	319.55	4,021.37	5,488.90
Net Present Value (NPV10)	-1,458.43	6.63	491.56	-921.57	1,000.82	1,710.61	-397.49	1,985.04	2,903.04
Internal Rate of Return (IRR)	-14.93%	10.11%	18.35%	-5.49%	27.16%	39.44%	3.39%	44.00%	59.40%
State Company (Nalcor)									
Net Cash Flow (NCF)	-151.51	107.23	186.76	-56.75	274.23	398.13	35.51	446.82	609.88
Net Present Value (NPV10)	-162.05	0.74	54.62	-102.40	111.20	190.07	-44.17	220.56	322.56
Internal Rate of Return (IRR)	-14.93%	10.11%	18.35%	-5.49%	27.16%	39.44%	3.39%	44.00%	59.40%
Government Revenue (Undiscounted)									
Total Government (Federal & Provincial)									
With Nalcor NCF	-546.19	980.80	1,919.26	53.05	3,081.88	4,255.16	702.55	4,738.13	6,592.65
Without Nalcor NCF	-394.68	873.57	1,732.50	109.80	2,807.65	3,857.03	667.04	4,291.31	5,982.77
Provincial Government Total									
With Nalcor NCF	-285.69	698.82	1,472.25	117.51	2,450.08	3,363.80	572.10	3,743.89	5,255.51
Without Nalcor NCF	-134.18	591.59	1,285.49	174.26	2,175.85	2,965.67	536.59	3,297.07	4,645.63
Direct									
Federal (CIT)	-260.50	281.98	447.01	-64.46	631.80	891.36	130.45	994.24	1,337.14
Provincial (CIT)	-243.13	263.18	417.21	-60.16	589.68	831.94	121.76	927.95	1,248.00
Subtotal – Total CIT	-503.63	545.16	864.22	-124.62	1,221.48	1,723.30	252.21	1,922.19	2,585.14
Royalty	108.95	256.76	360.62	234.42	843.33	808.16	414.83	1,014.56	1,232.55
Profit Share	0.00	71.65	507.66	0.00	742.84	1,325.57	0.00	1,354.56	2,165.08
Subtotal – Total Province	-134.18	591.59	1,285.49	174.26	2,175.85	2,965.67	536.59	3,297.07	4,645.63
Local Share [2]									
at 1% of Royalty	1.09	2.57	3.61	2.34	8.43	8.08	4.15	10.15	12.33
at 2% of Royalty	2.18	5.14	7.21	4.69	16.87	16.16	8.30	20.29	24.65
at 3% of Royalty	3.27	7.70	10.82	7.03	25.30	24.24	12.44	30.44	36.98
Equity Participation (Nalcor 10%)[3]									
Net Cash Flow (NCF)	-151.51	107.23	186.76	-56.75	274.23	398.13	35.51	446.82	609.88

1. Based on a Canadian-United States dollar (CND-USD) exchange rate of 0.90 and transportation costs of CND $2.00 per bbl; e.g., USD $85/0.90 - CND $2.00 = CND $92.44
2. Local includes only the modeled share of Provincial government royalties; it is a subset of the Provincial share; it does not include indirect taxes such as property tax.
3. Analysis assumes Nalcor to be fully taxable and modeled as a 10% full working interest partner.

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income tax, royalties, and profit sharing over the 26-year life of the project is $3,532 million, or $136 million per year, while the federal government revenue from corporate income tax is $996 million, or $38 million per year.

In terms of local sharing of benefits, the amounts range from $7.1 million to $21.3 million, depending on the royalty percentage (i.e., 1%, 2% or 3%) applied. This corresponds to $273,000-$821,000 in local revenues annually over the 26-year life of the project. The province may decide to invest some of its share of the total revenues in the region to diversify the economy.

As illustrated in Figure 29, for the deep well disposal of wastewater option, the net present value (NPV) calculations indicate that the project is viable for all combinations of oil price and recoverable reserve estimate except at 100 million barrels recoverable at a price of $50 US per barrel.

As discussed in more detail by Rodgers (2015), the sensitivity to a number of changes in key variables was also tested, including:

- well cost variation (i.e., -25% and +50% from the base case drilling and completion costs in Figure 27);
- requirement for the proponent to make a $100 million up-front investment in public road construction and upgrading to mitigate congestion that is expected to occur during construction and production;
- introduction of a 1% environmental protection levy on the project to address *"added costs through the generation of potential negative socio-economic externalities"*;
- discount rate variation (i.e., rates of 0%, 5%, 10%, 15% and 20%) to reflect different levels of business risk resulting from the geological uncertainty; and
- exchange rate sensitivity (i.e., $Can/$US of 0.8, 0.9 and 1.0).

The sensitivity to these parameters did not result in any significant change in project viability from the base case assumptions (i.e., 150 million barrels recoverable, $85 US per barrel).

The *"risk associated with the key project parameters – price, recoverable reserves, CapEx, and OpEx"* was also considered, and *"the most critical parameters to economic success are price … and recoverable reserves"* (Rodgers, 2015). With respect to the overall economic feasibility, Rodgers (2015) concludes that *"the project appears to be attractive enough to move to the next stage, and consider drilling another well with the hope of confirming the reserve size estimates and costs"*.

In addition to considering the economic feasibility from the perspective of the proponent and investors in the project, it is also critical to consider the annual contribution of the project to provincial revenues. This involves assessing the potential impact of the project on the fiscal position of the province.

Since provincial government revenues are in the order of $6.8 billion annually (NLDF, 2016a), the annual fiscal impact of this project (i.e. $84-$136 million) would be in the order of 1.2-2.0% of revenues. While not an insignificant source of revenue, the annual contribution would be far less than the revenues normally attributed to offshore oil and gas activities, including royalties. The revenues would be more in line with revenues from lotteries, vehicle and driver licence fees, tobacco tax, and insurance company tax (NLDF, 2016a).

In other words, the annual provincial revenues from the illustrative project, while perhaps very important to Western Newfoundland under certain revenue-sharing models, cannot be considered a "game changer" with respect to the fiscal position of Newfoundland and Labrador.

Figure 29 (see page 65). Summary of economic results for deep well disposal of wastewater (Rodgers, 2015).

GREEN POINT SHALE ECONOMIC RESULTS Canadian Dollars – Real Value (Millions)									
Water Disposal – Deep Well Injection (DW-Inj)									
	Recoverable Reserves								
	100 MM bbls			**150 MM bbls**			**200 MM bbls**		
United States Dollar Price Per bbl	$50	$85	$100	$50	$85	$100	$50	$85	$100
Canadian Dollar Equivalent Price [1]	$53.56	$92.44	$109.11	$53.56	$92.44	$109.11	$53.56	$92.44	$109.11
Project									
Net Cash Flow (NCF)	322.88	2,303.60	3,099.38	1,632.59	4,473.88	5,713.96	2,823.94	6,688.04	8,339.27
Net Present Value (NPV10)	-413.33	893.77	1,399.55	455.76	2,261.39	3,035.86	1,222.78	3,640.94	4,666.79
Internal Rate of Return (IRR)	3.33%	25.19%	33.81%	17.65%	48.06%	60.56%	30.77%	70.03%	86.03%
Private Investor (Shoal Point Energy)									
Net Cash Flow (NCF)	290.59	2,073.24	2,789.44	1,469.33	4,026.50	5,142.57	2,541.55	6,019.23	7,505.34
Net Present Value (NPV10)	-371.99	804.39	1,259.60	410.19	2,035.25	2,732.27	100.50	3,276.84	4,200.11
Internal Rate of Return (IRR)	3.33%	25.19%	33.81%	17.65%	48.06%	60.56%	30.77%	70.03%	86.03%
State Company (Nalcor)									
Net Cash Flow (NCF)	32.29	230.36	309.94	163.26	447.39	571.40	282.39	668.80	833.93
Net Present Value (NPV10)	-41.33	89.38	139.96	45.58	226.14	303.59	122.28	364.09	466.68
Internal Rate of Return (IRR)	3.33%	25.19%	33.81%	17.65%	48.06%	60.56%	30.77%	70.03%	86.03%
Government Revenue (Undiscounted)									
Total Government (Federal & Provincial)									
With Nalcor NCF	407.82	2,488.88	3,428.53	1,725.33	4,975.95	6,352.21	3,157.61	7,428.89	9,268.97
Without Nalcor NCF	375.53	2,258.52	3,118.59	1,562.07	4,528.56	5,780.81	2,875.22	6,760.09	8,435.04
Provincial Government Total									
With Nalcor NCF	283.15	1,948.87	2,722.67	1,327.09	3,979.70	5,093.97	2,507.67	5,966.50	7,457.73
Without Nalcor NCF	250.86	1,718.51	2,412.73	1,163.83	3,532.31	4,522.57	2,225.28	5,297.70	6,623.80
Direct									
Federal (CIT)	124.67	540.01	705.86	398.24	996.25	1,258.24	649.94	1,462.39	1,811.24
Provincial (CIT)	116.35	504.00	658.81	371.70	929.84	1,174.36	606.61	1,364.89	1,690.49
Subtotal – Total CIT	241.02	1,044.01	1,364.67	769.94	1,926.09	2,432.60	1,256.55	2,827.28	3,501.73
Royalty	134.51	339.83	434.30	352.91	711.23	864.83	568.50	1,070.24	1,288.57
Profit Share	0.00	874.68	1,319.62	439.22	1,891.24	2,483.38	1,050.17	2,862.57	3,644.74
Subtotal – Total Province	250.86	1,718.51	2,412.73	1,163.83	3,532.31	4,522.57	2,225.28	5,297.70	6,623.80
Local Share [2]									
at 1% of Royalty	1.35	3.40	4.34	3.53	7.11	8.65	5.69	10.70	12.89
at 2% of Royalty	2.69	6.80	8.69	7.06	14.22	17.30	11.37	21.40	25.77
at 3% of Royalty	4.04	10.19	13.03	10.59	21.34	25.94	17.06	32.11	38.66
Equity Participation (Nalcor 10%)[3]									
Net Cash Flow (NCF)	32.29	230.36	309.94	163.26	447.39	571.40	282.39	668.80	833.93

1. Based on a Canadian-United States dollar (CND-USD) exchange rate of 0.90 and transportation costs of CND $2.00 per bbl; e.g., USD $85/0.90 - CND $2.00 = CND $92.44
2. Local includes only the modeled share of Provincial government royalties; it is a subset of the Provincial share; it does not include indirect taxes such as property tax.
3. Analysis assumes Nalcor to be fully taxable and modeled as a 10% full working interest partner.

Rodgers Oil & Gas Consulting with input from the Panel

9.3.3 Assessment of Impact on Employment, Gross Domestic Product, and Tax

In evaluating the economic impact of the illustrative project on Western Newfoundland, and in particular on the Stephenville-Port au Port local area, the creation of employment opportunities, both direct employment and spin-off employment, must be considered. In particular, the associated potential Gross Domestic Product (GDP) and incomes generated in Newfoundland and Labrador from the capital and operating expenditures for the project need to be examined. It is the combination of employment, income, and GDP revenue, supplemented by royalty sharing within the local area, that would be the basis for stimulation of regional economic development, which may emanate from an unconventional oil and gas industry in Western Newfoundland.

Figure 30 summarizes the estimates of the total expenditures; the expenditures in Newfoundland and Labrador; and the associated direct employment, in person-years and annually, in the province and in the Stephenville-Port au Port region for a project that uses deep well disposal of flowback and produced water. Figure 31 summarizes the corresponding estimates for a project that uses off-site treatment of flowback and produced water.

These estimates are based on information provided to the Panel (NLDNR, 2015) (PSAC, 2016a) with respect to capital and operating costs for the 480-well unconventional oil and gas development scenario. Further details regarding these estimates are presented in (NLHFRP, 2016a).

9.3.3.1 Estimate of Direct Employment Impact

For each of the capital and operating expenditures, the Panel estimated the percentage of the expenditure that would occur within the province and also estimated the corresponding labour component. The estimates for the direct employment are based on average salaries of $90,000 for labour arising from the capital expenditures and $75,000 for labour arising from the operating expenditures within the different categories listed in Figures 30 and 31.

In estimating the direct employment impacts of the illustrative project, the Panel considered that the capital expenditures would require specialized labour for a relatively short period of time (i.e., six years). The province does not have a history of unconventional oil and gas development and, as such, many of the required skills are unlikely to exist currently within the province. Consequently, for the capital expenditures, the provincial labour content is expected to be approximately 36% of the total labour content, with approximately 13% coming from the Stephenville-Port au Port local area (NLHFRP, 2016e). For the operating expenditures, 80% of the provincial labour content is expected to come from the Stephenville-Port au Port local area.

The direct employment estimates do not include potential employment from operation of the electricity generation and distribution system nor from the operation of the marine terminal. The scale of both of these activities, and hence the level of employment, depends on a number of factors, including plans for the utilization of the associated gas and the possibility of on-island treatment of wastewater.

As noted in Figure 30, for the option using deep well disposal of flowback water, the total direct employment in the province from the capital expenditures is estimated to be 3,573 person-years. The corresponding employment in the Stephenville-Port au Port local area is estimated to be 1,320 person-years. As shown in Figure 30, this represents the equivalent of 595 full-time jobs annually in the province, including 220 full-time equivalent jobs in the Stephenville-Port au Port local area over the six-year period of constructing the 480 wells and associated infrastructure.

Figure 30 shows that the total direct employment in the province from the operating expenditures is estimated to be 811 person-years. Of this amount, 649 person-years of employment would be in the Stephenville-Port au Port local area. This represents an average of 31 full-time jobs annually in the province, including 25 full-time equivalent jobs in the Stephenville-Port au Port local area over the 26-year life of the project.

DESCRIPTION	EXPENDITURES ($M)		Direct NL Employment Person Years (PY)	Direct NL Employment Annually for 6 Years	Direct Stephenville-Port au Port Employment Annually for 6 Years
Capital Expenditures (CAPEX)	Total	NL			
Production Well Drilling	$3,380.3	$2,871.3	1,885	314	126
Disposal Well Drilling	$74.4	$63.2	41	7	3
Central Proc. Facilities & Main Gathering Lines	$80.0	$74.0	240	40	13
Central Storage & Loading Facilities	$120.0	$111.0	360	60	20
Field Oil and Gas Gathering Lines	$34.3	$31.7	103	17	6
Treatment Facilities	$34.3	$31.7	103	17	6
Main Processing Lines	$80.0	$74.0	240	40	13
Lease and Install Electric Turbines	$40.0	$40.0	0	0	0
Electrical Distribution	$40.0	$40.0	0	0	0
Marine Terminal	$150.0	$138.8	451	75	25
Pre-development Capex	$50.0	$46.3	150	25	8
TOTAL Capital	**$4,083.3**	**$3,521.9**	**3,573**	**595**	**220**
Operating Expenditures (OPEX)	Total	NL	Direct NL Employment Person Years (PY)	Direct NL Employment Annually for 26 Years	Direct Stephenville-Port au Port Employment Annually for 26 Years
Field Oil OPEX (Variable)	$90.0	$90.0	100	4	3
Field Oil OPEX (Fixed)	$60.0	$60.0	0	0	0
Storage & Loading Facilities OPEX	$150.0	$150.0	167	6	5
Well OPEX	$230.4	$230.4	256	10	8
Well Abandonment	$48.0	$48.0	53	2	2
Field OPEX Gas (Fixed)	$22.5	$22.5	0	0	0
Field OPEX Gas (Variable)	$37.5	$37.5	0	0	0
Transport make-up water to well	$22.9	$22.9	51	2	2
Transport wastewater to injection	$83.0	$83.0	184	7	6
Deep well injection costs	$69.2	$69.2	0	0	0
Electricity OPEX	$25.0	$25.0	0	0	0
TOTAL Operating	**$838.5**	**$838.5**	**811**	**31**	**25**
GRAND TOTAL – Deep Well Disposal Option	$4,921.8	$4,360.4	4,384		

Figure 30. Expenditures and direct employment: Deep well disposal option.

DESCRIPTION	EXPENDITURES ($M)		Direct NL Employment Person Years (PY)	Direct NL Employment Annually for 6 Years	Direct Stephenville-Port au Port Employment Annually for 6 Years
Capital Expenditures (CAPEX)	Total	NL			
Production Well Drilling	$3,380.3	$2,871.3	1,885	314	126
Disposal Well Drilling	$18.6	$15.6	10	1	0
Central Proc. Facilities & Main Gathering Lines	$80.0	$74.0	240	40	13
Central Storage & Loading Facilities	$120.0	$111.0	360	60	20
Field Oil and Gas Gathering Lines	$34.3	$31.7	103	17	6
Treatment Facilities	$34.3	$31.7	103	17	6
Main Processing Lines	$80.0	$74.0	240	40	13
Lease and Install Electric Turbines	$40.0	$40.0	0	0	0
Electrical Distribution	$40.0	$40.0	0	0	0
Marine Terminal	$150.0	$138.8	451	75	25
Pre-development Capex	$50.0	$46.3	150	25	8
TOTAL Capital	**$4,027.5**	**$3,474.5**	**3,542**	**590**	**217**
Operating Expenditures (OPEX)	Total	NL	Direct NL Employment Person Years (PY)	Direct NL Employment Annually for 26 Years	Direct Stephenville-Port au Port Employment Annually for 26 Years
Field Oil OPEX (Variable)	$90.0	$90.0	100	4	3
Field Oil OPEX (Fixed)	$60.0	$60.0	0	0	0
Storage & Loading Facilities OPEX	$150.0	$150.0	167	6	5
Well OPEX	$230.4	$230.4	256	10	8
Well Abandonment	$48.0	$48.0	53	2	2
Field OPEX Gas (Fixed)	$22.5	$22.5	0	0	0
Field OPEX Gas (Variable)	$37.5	$37.5	0	0	0
Transport make-up water to well	$22.9	$22.9	51	2	2
Flow-back and produced water - transport costs	$3,459.0	$0.0	0	0	0
Flow-back and produced water - treatment costs	$415.1	$8.3	0	0	0
Electricity OPEX	$25.0	$25.0	0	0	0
TOTAL Operating	**$4,560.3**	**$694.6**	**627**	**24**	**19**
GRAND TOTAL – Deep Well Disposal Option	$8,587.8	$4,169.1	4,169		

Figure 31. Expenditures and direct employment: Off-site treatment option

As shown in Figure 31, the direct employment for the capital expenditures for the project using off-site treatment of flowback water is similar to that for deep well disposal. Total direct employment in the province from the capital expenditures is estimated to be 3,542 person-years resulting in direct employment in the Stephenville-Port au Port local area of 1,307 person-years. This represents 590 full-time equivalent jobs annually in the province, including 217 full-time equivalent jobs in the Stephenville-Port au Port local area over the six-year period of constructing the 480 wells and associated infrastructure.

The total direct employment in the province from the operating expenditures is estimated to be 627 person-years, including 502 person-years of employment in the Stephenville-Port au Port local area. This represents 24 full-time equivalent jobs annually in the province, including 19 full-time equivalent jobs in the Stephenville-Port au Port local area over the 26-year life of the project.

9.3.3.2 Direct, Indirect, and Induced Employment and Gross Domestic Product Impacts

Based on the expenditure and direct employment estimates presented in Section 9.3.3.1, the Panel commissioned a study, which is included as Appendix R, of the broader potential economic impacts, including additional employment, gross domestic product, and tax impacts (EcoTec, 2016). Appendix R discusses the detailed methodology used for an input-output analyses of the base case scenario (150 million barrels of oil at $85 US per barrel) for both the deep well disposal and off-site treatment options.

An input-output analysis estimates the indirect and induced employment for the 480-well project. The indirect employment corresponds to the employees of the suppliers of goods and services, while induced employment reflects the jobs arising from personal expenditures (e.g., household expenditures) by individuals working directly or indirectly on the project. Since much of the capital equipment is expected to be imported into the province, there would also be considerable indirect and induced employment outside of the province as a result of the project.

As summarized in Figure 32, the total direct, indirect, and induced employment in Newfoundland and Labrador arising from the capital expenditures for the deep well disposal option is estimated to be 6,612 person-years, or 1,102 full-time equivalent jobs annually in the province over a six-year period. Within the Stephenville-Port au Port local area, a total of 312 annual full-time equivalent jobs is estimated to result from capital expenditures. For the operating expenditures, the total direct, indirect, and induced employment for Newfoundland and Labrador is estimated to be 1,858 person-years. This corresponds to 72 full-time equivalent jobs annually, including 38 full-time equivalent jobs in the Stephenville-Port au Port local area over a 26-year period.

CAPITAL EXPENDITURES: DIRECT, INDIRECT AND INDUCED EMPLOYMENT IN PERSON YEARS (PY) AND ANNUALLY FOR 6 YEARS: DEEP WELL DISPOSAL OPTION	DIRECT		INDIRECT		INDUCED		TOTAL	
	PY	Annual	PY	Annual	PY	Annual	PY	Annual
Stephenville – Port au Port	1320	220	434	72	119	20	1873	312
Newfoundland and Labrador	3573	595	2278	380	761	127	6612	1102
OPERATING EXPENDITURES: DIRECT, INDIRECT AND INDUCED EMPLOYMENT IN PERSON YEARS (PY) AND ANNUALLY FOR 26 YEARS: DEEP WELL DISPOSAL OPTION	DIRECT		INDIRECT		INDUCED		TOTAL	
	PY	Annual	PY	Annual	PY	Annual	PY	Annual
Stephenville – Port au Port	649	25	264	10	65	3	978	38
Newfoundland and Labrador	811	31	808	31	238	9	1858	72

Figure 32. Direct, indirect and induced employment: Deep well disposal option.

CAPITAL EXPENDITURES: DIRECT, INDIRECT AND INDUCED EMPLOYMENT IN PERSON YEARS (PY) AND ANNUALLY FOR 6 YEARS: OFF-SITE TREATMENT OPTION	DIRECT		INDIRECT		INDUCED		TOTAL	
	PY	Annual	PY	Annual	PY	Annual	PY	Annual
Stephenville – Port au Port	1307	218	430	72	118	20	1855	310
Newfoundland and Labrador	3542	590	2250	375	752	125	6544	1090
OPERATING EXPENDITURES: DIRECT, INDIRECT AND INDUCED EMPLOYMENT IN PERSON YEARS (PY) AND ANNUALLY FOR 26 YEARS: OFF-SITE TREATMENT OPTION	DIRECT		INDIRECT		INDUCED		TOTAL	
	PY	Annual	PY	Annual	PY	Annual	PY	Annual
Stephenville – Port au Port	502	19	267	10	56	2	825	31
Newfoundland and Labrador	627	24	729	28	203	8	1557	60

Figure 33. Direct, indirect and induced employment: Off-site treatment option.

With respect to the total direct, indirect, and induced employment in Newfoundland and Labrador from the capital and operating expenditures for the off-site treatment option, as shown in Figure 33, the employment numbers drop slightly from those generated with the deep well disposal option. The direct, indirect, and induced employment is estimated to be 6,544 person-years, or 1,090 full-time equivalent jobs annually in the province from capital expenditures, with a total of 310 annual direct, indirect, and induced full-time equivalent jobs in the Stephenville-Port au Port local area over a six-year period. For the operating expenditures, the direct, indirect, and induced employment in the province is estimated to be 1,557 person-years, or 60 full-time equivalent jobs annually, including 31 full-time equivalent jobs annually in the Stephenville-Port au Port local area over a 26-year period.

As noted in Appendix R, the contributions to Gross Domestic Product (GDP) from the capital and operating expenditures of the project are important to consider. This represents *"the value added generated within an economy and is widely used to measure the size, and growth rate, of national and provincial economies"* (EcoTec, 2016). As with the employment impacts, GDP impacts may be direct, indirect, or induced.

The direct GDP corresponds to the on-site capital and operating expenditures (e.g., payment of salaries and wages to drilling crews and staff at production facilities) within a region (i.e., the Stephenville-Port au Port local area, Newfoundland and Labrador, or the rest of Canada). The indirect GDP corresponds to expenditures by suppliers of goods and services to the project, and includes the expenditures by suppliers to suppliers. For example, this would include GDP from the supply of fuel to a cement plant that delivers the cement that is used during well construction. As noted in Appendix R, induced GDP corresponds to *"the consumer expenditures of employees of all the firms that benefited from the direct and indirect impacts"* (EcoTec, 2016).

Figure 34 shows the breakdown of GDP generated in Stephenville-Port au Port local area, in Newfoundland and Labrador, and in the rest of Canada for the capital and operating expenditures for the deep well disposal option. Figure 35 provides the same data for the off-site treatment option. In 2014, the provincial GDP was approximately $33.5 billion (NLSA, 2015), so the capital expenditures for the project for both options of approximately $115 million represent approximately 0.35% of provincial GDP.

While the GDP from the operating expenditures for each option represents only 0.08-0.09% of provincial GDP, the overall contribution to the provincial GDP will be higher since the revenues from the sale of oil and gas (adjusted to take into account other business costs) must be included. It is expected that during production, the total annual contribution of the project to provincial GDP would be in the order of $350-$500 million, depending on the option

CAPITAL EXPENDITURES: DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP), TOTAL AND AVERAGE ANNUAL FOR 6 YEARS: DEEP WELL DISPOSAL OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total	Annual	Total	Annual	Total	Annual	Total	Annual
Stephenville – Port au Port	$216.2	$36.0	$29.6	$4.9	$21.5	$3.6	$267.4	$44.6
Newfoundland and Labrador	$402.6	$67.1	$188.2	$31.4	$104.4	$17.4	$695.2	$115.8
Rest of Canada			$1,597.6	$266.3	$538.1	$89.7	$2,135.7	$356.0
OPERATING EXPENDITURES: DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP), TOTAL AND AVERAGE ANNUAL FOR 26 YEARS: DEEP WELL DISPOSAL OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total	Annual	Total	Annual	Total	Annual	Total	Annual
Stephenville – Port au Port	$520.2	$20.0	$25.1	$1.0	$11.2	$0.4	$556.6	$21.4
Newfoundland and Labrador	$534.8	$20.6	$78.7	$3.0	$30.2	$1.2	$643.7	$24.8
Rest of Canada			$138.1	$5.3	$64.1	$2.5	$202.2	$7.8
TOTAL DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP): DEEP WELL DISPOSAL OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total		Total		Total		Total	
Stephenville – Port au Port	$736.4		$54.7		$32.7		$823.8	
Newfoundland and Labrador	$937.4		$266.9		$134.6		$1,338.9	
Rest of Canada			$1,735.7		$602.2		$2,337.9	

Figure 34. Direct, indirect and induced gross domestic product (GDP): Deep well disposal option.

selected for disposal of wastewater (NLHFRP, 2016d). This represents 1.0-1.5% of the $33.5 billion annual GDP. Given that the oil and gas industry accounts for over 25% of the provincial GDP (NLDF, 2016b), the overall contribution of the project to the oil and gas sector's GDP is expected to be relatively small.

CAPITAL EXPENDITURES: DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP), TOTAL AND AVERAGE ANNUAL FOR 6 YEARS: OFF-SITE TREATMENT OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total	Annual	Total	Annual	Total	Annual	Total	Annual
Stephenville – Port au Port	$214.7	$36.3	$29.3	$4.9	$21.3	$3.6	$265.3	$44.2
Newfoundland and Labrador	$399.4	$66.6	$185.9	$31.0	$103.3	$17.2	$688.6	$114.8
Rest of Canada			$1,575.6	$262.6	$531.1	$88.5	$2,106.7	$351.1
OPERATING EXPENDITURES: DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP), TOTAL AND AVERAGE ANNUAL FOR 26 YEARS: OFF-SITE TREATMENT OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total	Annual	Total	Annual	Total	Annual	Total	Annual
Stephenville – Port au Port	$431.0	$16.6	$25.5	$1.0	$9.5	$0.4	$466.1	$18.0
Newfoundland and Labrador	$442.3	$17.0	$71.2	$2.7	$25.5	$1.0	$539.1	$20.7
Rest of Canada			$113.8	$4.4	$53.7	$2.1	$167.5	$6.5
TOTAL DIRECT, INDIRECT AND INDUCED GROSS DOMESTIC PRODUCT (GDP): OFF-SITE TREATMENT OPTION	DIRECT ($ MILLION)		INDIRECT ($ MILLION)		INDUCED ($ MILLION)		COMBINED GDP ($ MILLION)	
	Total		Total		Total		Total	
Stephenville – Port au Port	$645.8		$54.8		$30.8		$731.4	
Newfoundland and Labrador	$841.7		$257.1		$128.8		$1,227.7	
Rest of Canada			$1,689.4		$584.9		$2,274.2	

Figure 35. Direct, indirect and induced gross domestic product (GDP): Off-site treatment option.

9.3.3.3 Other Economic Impacts

Other sources of economic benefit from the capital and operating expenditures include income tax, sales and excise taxes, and tax on corporate profits. This is in addition to any taxes from the sale of oil and gas. Figure 36 summarizes the taxes collected by the provincial and federal governments for each of the options for both capital and operating expenditures. For both options, the provincial tax revenue generated from the capital and operating expenditures only is estimated to be approximately $100 million. Note that the provincial and federal taxes from the sale of 150 million barrels of oil are included in the discussion in Section 9.3.2 of this report.

DEEP WELL DISPOSAL OPTION	CONSTRUCTION ($ MILLION)	PRODUCTION ($ MILLION)	TOTAL ($ MILLION)
Newfoundland and Labrador			
Income Tax	$25.7	$8.0	$33.7
Sales and Excise Tax	$37.1	$19.2	$56.3
Tax on Corporate Profits	$5.8	$14.9	$20.7
Total NL	**$68.5**	**$42.2**	**$110.7**
Federal Government			
Income Tax	$41.8	$13.8	$55.6
Sales and Excise Tax	$17.3	$8.9	$26.2
Tax on Corporate Profits	$9.9	$25.5	$35.4
Total Federal	**$68.9**	**$48.2**	**$117.1**
Total NL + Federal	**$137.5**	**$90.4**	**$227.9**
OFF-SITE TREATMENT OPTION	**CONSTRUCTION ($ MILLION)**	**PRODUCTION ($ MILLION)**	**TOTAL ($ MILLION)**
Newfoundland and Labrador			
Income Tax	$25.4	$6.4	$31.9
Sales and Excise Tax	$36.6	$12.9	$49.5
Tax on Corporate Profits	$5.7	$12.7	$18.5
Total NL	**$67.8**	**$32.1**	**$99.9**
Federal Government			
Income Tax	$41.5	$11.0	$52.4
Sales and Excise Tax	$17.0	$6.0	$23.0
Tax on Corporate Profits	$9.8	$21.7	$31.5
Total Federal	**$68.3**	**$38.7**	**$107.0**
Total NL + Federal	**$136.1**	**$70.7**	**$206.9**

Figure 36. Federal and provincial taxes associated with expenditures during construction and production (adapted from EcoTec, 2016).

	DIRECT	INDIRECT	INDUCED	TOTAL
Avalon Peninsula	0	103	38	141
Burin Peninsula	0	1	2	3
Burgeo-Channel-Port aux Basques	0	2	2	4
Port-au-Port-Stephenville	**532**	**50**	**41**	**623**
Corner Brook-Deer Lake	0	52	14	66
Gander-Grand Falls-Windsor	0	7	5	12
Bonavista-Clarenville	0	3	3	6
Baie Verte-Lewisporte-Twillingate	0	18	6	24
Northern Peninsula	0	2	2	4
Labrador	0	22	6	28
Total Newfoundland and Labrador	**532**	**260**	**119**	**912**
Other provinces	0	184	126	310
Canada	**532**	**445**	**245**	**1,222**

Figure 37. Direct, indirect and induced employment associated with $100 million of expenditure on road construction (EcoTec, 2016).

As illustrated by Figure 37, if the proponent is required to construct or upgrade roads to alleviate congestion, this is estimated to cost $100 million and is expected to yield an additional 623 person-years of employment within the Stephenville-Port au Port local area and a total of 912 person-years of employment within the province. Assuming that road construction and upgrading would be completed within a three-year period, this corresponds to approximately 300 full-time equivalent jobs throughout the province during this period, including approximately 200 full-time equivalent jobs for the Stephenville-Port au Port local area.

The final economic impacts considered by the Panel are those from tourism expenditures in Western Newfoundland. Any increases in local employment or GDP from project-related travel to Western Newfoundland are captured in the indirect and induced employment and GDP analyses discussed in Section 9.3.3.2. The Panel, however, heard concerns from a number of people involved in the tourism industry about potential negative impacts on tourism operations if unconventional oil and gas development proceeds in Western Newfoundland.

Figure 38 illustrates the impact on employment per $100 million of tourism expenditure in Western Newfoundland. In this analysis, the tourism expenditures were split between the Northern Peninsula ($70 million) and the Stephenville-Port au Port local area ($30 million). For every $100 million in tourism expenditure within Western Newfoundland, there would be716 jobs in Western Newfoundland, including 201 full-time equivalent jobs in the Stephenville-Port au Port area and 461 full-time equivalent jobs on the Northern Peninsula.

As discussed in Section 6.3, the current annual tourism expenditures in Western Newfoundland are estimated to be $176.4 million. Should tourism expenditures in Western Newfoundland change as a result of unconventional oil and gas development, the associated employment gains or losses would need to be factored into the anticipated employment gains discussed earlier. For example, if the introduction of unconventional oil and gas development in Western Newfoundland results in a 10% change in tourism expenditures in the region, corresponding to an increase

	DIRECT	INDIRECT	INDUCED	TOTAL
Avalon Peninsula	55	26	27	108
Burin Peninsula	3	1	1	5
Burgeo-Channel-Port aux Basques	2	1	1	5
Port-au-Port-Stephenville	**171**	**14**	**16**	**201**
Corner Brook-Deer Lake	29	10	10	49
Gander-Grand Falls-Windsor	10	4	4	19
Bonavista-Clarenville	3	2	3	8
Baie Verte-Lewisporte-Twillingate	5	3	3	11
Northern Peninsula	400	27	34	461
Labrador	7	4	4	15
Total Newfoundland and Labrador	**686**	**93**	**103**	**882**
Other provinces	141	174	154	469
Canada	**827**	**267**	**257**	**1,350**

Figure 38. Direct, indirect and induced employment associated with $100 million of tourism expenditures in Western Newfoundland (EcoTec, 2016).

or decrease of $17.6 million, there would be a gain or loss of approximately 156 full-time jobs in the province, including 126 jobs in Western Newfoundland.

If the introduction of unconventional oil and gas results in a loss of tourism revenues, the corresponding loss of employment may be significant given the limited number of full-time equivalent jobs estimated to be created in Western Newfoundland once the wells have been put into production (EcoTec, 2016). An alternative perspective is that an increase in tourism expenditures could occur in the region since out-of-province workers will bring their families and friends to the region as tourists while they are working on a project, and they are likely to return to Western Newfoundland as tourists in the future.

9.3.3.4 Summary of Employment and Economic Impact

Relatively speaking, while not transformative on an annual basis to the province from either employment or fiscal perspectives, a project of the scale considered by the Panel has the potential to generate local employment and economic benefits over a 26-year period. In view of this, the illustrative project would be a regional economic development opportunity that could be significant to the people of Western Newfoundland, and, in particular, to the people of the Stephenville-Port au Port local area.

From an employment perspective in the Stephenville-Port au Port area, an analysis of the project shows that approximately 2,500 person-years of employment, or slightly more and 400 full-time equivalent jobs annually, would be created during the six-year period when construction of the wells and associated infrastructure, including the construction and upgrading of roads, would be carried out. When the construction is completed and the wells are in production, the number of jobs in the Stephenville-Port au Port local area would be on the order of 30-40 full-time jobs annually.

There may be higher levels of local employment depending on decisions about utilization of the associated gas and treatment of wastewater within the province rather than requiring off-island treatment. From an employment impact perspective, it will be important to understand the extent of impact, if any, on existing employment (i.e., from tourism or other sectors) from unconventional oil and gas development. For the individuals who have employment opportunities, the benefits go beyond financial to include satisfaction from being engaged in stimulating and interesting work, and increased self-esteem resulting from employment.

9.3.3.5 Traffic Considerations

One significant consideration is that of truck traffic during the construction and production phases of a development. Communities around Port au Port Bay, like most small coastal communities in Newfoundland, are comprised of homes built along a single road that runs through the community. For example, as noted in a submission to the Panel by the Town of Kippens, *"Route 460, also known as Kippens Road runs directly through the community and is the only access to the Port au Port Peninsula"* (Kippens, 2015). There are few back roads in the communities and traffic through a community would need to share the existing, albeit upgraded, roads.

The existing public roads around Port au Port Bay and Stephenville that could be affected by increased traffic during development and production are highlighted in Figure 39. Currently traffic on and off the Port au Port Peninsula is via Route 460, which runs from Stephenville and comes onto the peninsula along a short isthmus near Port au Port. Route 460 then runs south and follows the south coast of the peninsula. Access to Shoal Point is by a smaller road along the south side of East Bay and goes to Shoal Point via Boswarlos. Currently, access to Long Point requires turning off Route 460 at Abraham's Cove on the south coast of the peninsula and heading north on Route 463 along West Bay to Lourdes where a small road runs north to Long Point via Winterhouse and Black Duck Brook. Access to Point au Mal and Fox Island River is via a road that runs north from Route 460, just east of the isthmus at the start of the Port au Port Peninsula.

Figure 39. Existing roads around Port au Port Bay (adapted from Google Maps).
Figure 40 (see page 77). Summary of tranportation activity during construction and production.

TRANSPORTATION CONSIDERATIONS EXCLUDING OIL TRANSPORTATION, PRODUCTION SERVICING AND WELL ABANDONMENT	
Key Features of the Port au Port Bay Scenario	
Number of years to construct 480 wells	6
Number of years of production per well	20
Total recoverable oil (in barrels)	150,000,000
Number of wells constructed per year	80
Number of stages per well	15
Water flow-back (%)	50
Water/Oil ratio	0.77
Water, Proppant and Additive Assumptions	
Gallons of water per well for fracturing fluid	4,000,000
Tons of proppant per well	5,000
Gallons of additives per well	28,000
Truck Capacity Assumptions	
Tons of proppant per truckload	40
Gallons of water or additives per truckload	5,250
Equipment Transportation Assumptions	
Number of truckloads per well for drilling and completion equipment	122
Water Transportation to Well	
Number of truckloads per well	762
Number of truckloads per day	167
Number of truck movements per day	334
Additive Transportation to Well	
Number of truckloads per well	5
Number of truckloads per day	2
Number of truck movements per day	4
Proppant Transportation to Well	
Number of truckloads per well	125
Number of truckloads per day	27
Number of truck movements per day	56
Flow-back Water Transportation to Disposal or Treatment	
Number of truckloads per well	381
Number of truckloads per day	84
Number of truck movements per day	168
Produced Water Transportation to Disposal or Treatment	
Number of truckloads per well	1,925
Number of truckloads per day	127
Number of truck movements per day	254
SUMMARY	
Total truckloads per well	**3,320**
Average number of truckloads per day during construction	**309**
Average number of truck movements per day during construction	**590**
Average number of truckloads per day during production	**127**
Average number of truck movements per day during production	**254**

Based on the 480-well development scenario discussed in Section 9, Figure 40 provides a summary of the track traffic estimates (NLHFRP, 2016b) during construction and production. Four million gallons of make-up water (USGS, 2015) per well would be used along with 5,000 tons of proppant per well (Bleiwas, 2015). In addition, 28,000 gallons of additives per well would be required (Ferrer & Thurman, 2015). The estimates for truck traffic for the movement of equipment used during drilling, completion, and production are based on the recent published estimates (Goodman, et al., 2016) (Hart, Adams, & Schwartz, 2013), adjusted for efficiencies due to the anticipated number of wells per well pad. Truck capacities were provided in a submission to the Panel by the Petroleum Services Association of Canada (PSAC, 2016a).

If the primary mode of transportation is by truck, the number of truckloads of equipment, water, proppant, and chemicals required for the illustrative project would be on the order of 3,320 per well during construction and production. During six-year construction period, the number of truck movements per day would be approximately 600, which are primarily for the movement of drilling and completion equipment between well pads, the transportation of the components of hydraulic fracturing fluid (i.e., water, proppant, and additives), and the transportation of flowback for off-site treatment or disposal. Each truck load of water, additives, proppant, and flowback requires two truck movements. For example, one truck movement is required to take a load of proppant from a central supply location to the well pad and a return trip is required to reload from the central supply location. This implies one truck movement every minute during a 10-hour work day.

When all wells are in production, the number of truck movements per day would drop to approximately 250. These are primarily for the transportation of produced water for off-site treatment or deep well disposal. This implies approximately one truck movement every two to three minutes during a 10-hour work day.

Further discussion of the traffic impacts can be found in Section 14.2.4.

10 PUBLIC OPINION SURVEY AND SUMMARY OF WRITTEN SUBMISSIONS

10.1 MQO Research Public Opinion Survey

To gauge public opinion about oil and gas activity in Newfoundland and Labrador, in general, and about potential hydraulic fracturing operations in Western Newfoundland, in particular, the Panel commissioned an independent public opinion survey that was conducted by MQO Research. The MQO Research survey results (MQO, 2015) are included in Appendix O of this report.

The survey was conducted as a random telephone survey with residents throughout Newfoundland and Labrador who were over the age of 18. A total of 840 respondents completed the survey, including 200 respondents in Western Newfoundland to enable the responses from the region to be evaluated separately. Data collection was conducted between June 16th and July 4th, 2015. Appendix O includes a copy of the questionnaire used in the MQO Research survey, along with a breakdown of the survey results for Western Newfoundland.

The survey results indicate that a significant majority of the people in Newfoundland and Labrador (MQO, 2015) :

- have limited knowledge of oil and gas exploration in Newfoundland and Labrador and in Western Newfoundland;
- have limited knowledge of hydraulic fracturing operations;
- need more information about the oil and gas industry;
- agree that Western Newfoundland needs the jobs and revenues from oil and gas development in Western Newfoundland;
- agree that the oil and gas industry will create long-term benefits for Western Newfoundland;
- agree that there should be exploration for oil and gas in Western Newfoundland;
- agree that there should be a buffer zone of at least 25 km around Gros Morne National Park;

- do not agree that hydraulic fracturing operations should be carried out in Western Newfoundland;
- agree that the oil and gas industry has a social licence to operate offshore Newfoundland and Labrador (i.e., East Coast); and
- do not agree that the oil and gas industry has a social licence to carry out hydraulic fracturing operations in Western Newfoundland.

Of the respondents to the survey, 43% indicated that they oppose hydraulic fracturing operations in Western Newfoundland for reasons that include (MQO, 2015):

- greenhouse gases / more macro pollution and environment comments (55%);
- local water quality / contamination / more local and personal environment comments (53%);
- unknown risks (18%);
- no social licence / others are against it / negative media / negative effects in other areas (15%);
- soil contamination / destabilize the ground / earthquakes (12%); and
- health effects (10%).

Among the 20% of respondents to the survey who indicated they support hydraulic fracturing operations in Western Newfoundand, the primary reasons for support include (MQO, 2015):

- creates jobs / employment (42%);
- boost economy / help business (35%);
- believe it is safe / it's fine in other areas (20%); and
- it is better to have more resources (13%).

10.2 Independent Analysis of the MQO Research Public Opinion Survey Results

The Panel commissioned Dr. Roberto Martínez-Espiñeira, a Professor of Economics at Memorial University, to undertake a quantitative analysis of the MQO Research survey results. Dr. Martínez-Espiñeira's report, which is included as Appendix P to this report, goes *"beyond the descriptive statistics and comments that MQO Research provided"* (Martínez-Espiñeira, 2016).

Appendix P describes, analyzes, and discusses the information obtained from each of the questions included in the MQO Research survey. The study uses techniques that account for the nature of the original survey (e.g., categorical responses to questions), as well as important information conveyed through the "don't know/no response" options. Appendix P also discusses what the answer to each question implies for the other questions within the survey. For example, the analysis of the MQO Research survey evaluates whether individuals' self-reported knowledge about hydraulic fracturing operations affects the likelihood of individuals supporting or opposing hydraulic fracturing operations. A full discussion of the methodology employed in the analysis of the MQO Research survey is provided in Appendix P.

As noted by Martínez-Espiñeira (2016):

> *"There seems to be a relatively low level of self-reported knowledge about fracking and it is likely that some respondents even confuse terminology and are unaware that some types of O&G [oil and gas] exploration and extraction strategies that they support are in fact associated with hydraulic fracturing."*

The respondents who believe they are well-informed and have expressed opinions about employment prospects, economic growth, and tax revenue support hydraulic fracturing operations. Respondents who believe they know more, and are concerned more, about environmental impacts are much more likely to oppose such a development approach. In addition, the study found :

> *"Most of the people in the province share a high degree of optimism about and good will towards the oil and natural gas sector and that they accept and even welcome most of its operations. However, there remain many uncertainties surrounding the particular issue of hydraulic fracturing in Western NL [Newfoundland and Labrador], which is opposed by a larger proportion of the population than in other jurisdictions"* (Martínez-Espiñeira, 2016).

Martínez-Espiñeira (2016) also discusses why people expressed neutral responses to questions about hydraulic fracturing operations in Western Newfoundland. The primary conclusion is that the neutrality is due to the lack of information to perform a full cost-benefit analysis from a personal perspective, including a lack of personal knowledge on the topic of hydraulic fracturing. Martínez-Espiñeira (2016) states:

> *"Those who know more about fracking are much less likely to be neutral about it (that is, they are more likely to have made up their mind one way or another). But if they happen to be still neutral, they are more likely to say it is because they need more information about the risks and also about the benefits than those who know less about it".*

A sizable proportion of respondents to the MQO Research survey were undecided, or were "on the fence", about many of the issues considered. With respect to this point, Martínez-Espiñeira (2016) comments:

> *"Not surprisingly, those with lower levels of self-reported knowledge about the industry are more likely to state neutrality about the issues presented to them. In principle, all of this suggests a need to make available more information about the O&G [oil and gas] to the people of NL [Newfoundland and Labrador]. Information on environmental impacts and other risks would be the most common type of information requested".*

In the conclusion to the study, Martínez-Espiñeira (2016) reflects on the polarizing opinions held on the matter of hydraulic fracturing and notes:

> *"Indeed, and particularly when it comes to fracking in Western NL, we can see that opinions are subject to polarizing effects, with some informed respondents feeling strongly against it and others feeling strongly in favour. In general, however, fracking in Western NL is quite a controversial proposition."*

10.3 Review of Written Submissions to the Panel

The Panel commissioned an independent assessment of the written submissions received from individuals, groups, and organizations in response to the April 2015 request for input. Dr. Keith Storey, an Honorary Research Professor in the Department of Geography at Memorial University with expertise in assessing the social impact of resource development projects, prepared a synthesis and summary of the written submissions received. Dr. Storey's report (Storey, 2015) is included as Appendix N of this report.

The synthesis and summary covered the written submissions that were received by the Panel as of July 23, 2015. This included 488 submissions by individuals, 38 submissions by community organizations and groups and four submissions from companies or industry groups. Story (2015) describes the context for the assessment of the written submissions as follows:

> *"The report does not, nor is it intended to, stand in place of the submissions. Rather it attempts to summarize any collective views and the emphases/concerns given to or expressed regarding particular themes. As with any overview, it is a simplification of the views and arguments presented. Detail is necessarily lost, as is the tone or passion expressed in many of the submissions".*

SUMMARY OF INDIVIDUAL CONCERNS RECEIVED BY THE PANEL	
Frequency of Concern (# submissions)	**Concern**
Greater than 300	Groundwater/Surface water
151-200	Environmental impacts generally Public health Waste management (primarily water waste)
101-150	Socio-economic impacts Seismicity/Geological risk Air emissions/pollutants Management of additives Land (primarily environment/ecology/sustainability issues) Tourism Traffic/Transportation/Accident
51-100	Fisheries Regulatory oversight Water usage Sea/Marine ecosystems Fires/Explosions/Flares Wildlife/Birds/Plant life Climate change Real estate values Quality of life for residents Lack of baseline data
26-50	Social licence to operate Spills Risks/Rewards of fracking Noise
11-25	Long term community effects Wellbore integrity Site restoration/rehabilitation Long term environmental effects Fossil fuel use Lack of trust in companies Smell
3-10	Stress/Mental health (local resident) Public safety/Emergency planning Future risks of lawsuits Financial security/Insurance in the event of spills/restoration needs Worker health

Figure 41. Summary of concerns raised in submissions by individuals (adapted from Storey, 2015).

The majority of the individual letters (82%) were in the form of personal letters, while the balance (18%) were form letters. Just over half of the individuals making submissions identified where they lived, and approximately a third of the individuals who submitted to the Panel indicated they were from Western Newfoundland. Of the community groups and organizations that made written submissions to the Panel, approximately 80% were based in Newfoundland and

SUMMARY OF COMMUNITY GROUP/ORGANIZATION CONCERNS RECEIVED BY THE PANEL	
Frequency of Concern (# submissions)	**Concern**
Greater than 20	Groundwater/Surface water Waste management (primarily waste water management) Public health
16-20	Environmental impacts generally Regulatory oversight
10-15	Management of additives Tourism Air Emissions Seismicity/Geological risks Climate change Socio-economic impacts Fisheries Spills/Leaks Lack of baseline data

Figure 42. Summary of concerns raised in submissions by groups/organizations (adapted from Storey, 2015).

Labrador, with about half of those based in Western Newfoundland. As discussed in more detail in Appendix N, among the individuals and community organizations and groups that made submissions, the vast majority (95% of individuals and 87% of community organizations and groups) expressed views opposing hydraulic fracturing operations in Western Newfoundland. In both cases, the majority of submissions called for a ban on hydraulic fracturing.

As of July 23, 2015, only four companies or industry groups had made written submissions, including the Canadian Association of Petroleum Producers (CAPP) and the Petroleum Services Association of Canada (PSAC), and each of these submissions indicated support for hydraulic fracturing operations in Western Newfoundland within an appropriate regulatory framework and utilizing industry "best practices".

Some submissions expressed concerns about panel bias, panel composition, the locations of the public consultation sessions, and the Terms of Reference for the Panel.

The report results are *"of a high level, aggregate nature, and at best indicative of general attitudes and views"* (Storey, 2015). In undertaking the work described in Appendix N, each submission was reviewed and the areas of concern and statements of values were coded and recorded in a spreadsheet format, together with information about the submission where that was provided. In some submissions, the concerns were described in detail, while in other submissions one or more concerns were simply stated.

The primary areas of concern, as reported in Appendix N, are summarised in Figure 41 and Figure 42.

With respect to the written submissions from companies and industry groups, Story (2015) states:

> *"As noted earlier, three of the four industry/industry group submissions directly addressed most or all of the themes listed in the Panel's Terms of Reference. In addition, in three of the submissions emphasis was also given to fracking technology and legislation/regulations pertaining to fracking. In two cases concern was expressed over whether what was described as 'biased science' utilized by opponents of fracking to make their case would influence the Panel's decision".*

The results of a survey of its membership by the Qalipu Mi'Kmaq First Nation Band were submitted to the Panel (Qalipu, 2016). This survey was done in November 2015 and included 714 respondents, with the majority of the respondents from Western Newfoundland. As a result of the survey, the following conclusion was presented:

> *"To conclude and summarize, members have some degree of familiarity with fracking, the majority are aware of the positive and negative impacts, they do not support fracking in Newfoundland and Labrador, and do not think their view could be effected by the results of the provincial 'Fracking Review Panel'"* (Qalipu, 2016).

While the Panel's report deals with most of the concerns and comments received in the written submissions and summarised in Figures 41 and 42, the Panel received a number of suggestions that the province should pursue green energy alternatives to oil and gas resource development, in particular wind energy. While this matter is beyond the scope of the Panel's work and merits careful consideration in terms of public policy, it is important to understand that such alternatives do not eliminate some of the significant public concerns about unconventional oil and gas development and most other forms of onshore, large-scale energy development projects, including green energy alternatives.

As noted by the Union of Concerned Scientists, which advocates for a greater portion of renewable energy within the U.S., *"all energy sources have some impact on our environment"* (UCS, n.d.). When considering issues such as land disturbance from unconventional oil and gas development, it is important to keep in mind that other energy sources of any commercial scale, including green energy sources such as wind and solar, also have significant land disturbance during development and production.

Figure 43 shows the sites of 12 wind turbines that are part of the Laurel Hill Windpower Project (Duke, 2012) in Lycoming County, Pennsylvania, where a series of 30 2.3 megawatt (MW) wind turbines are located in close proximity

Figure 43. Well pads and wind turbines, Lycoming County, Pennsylvania.

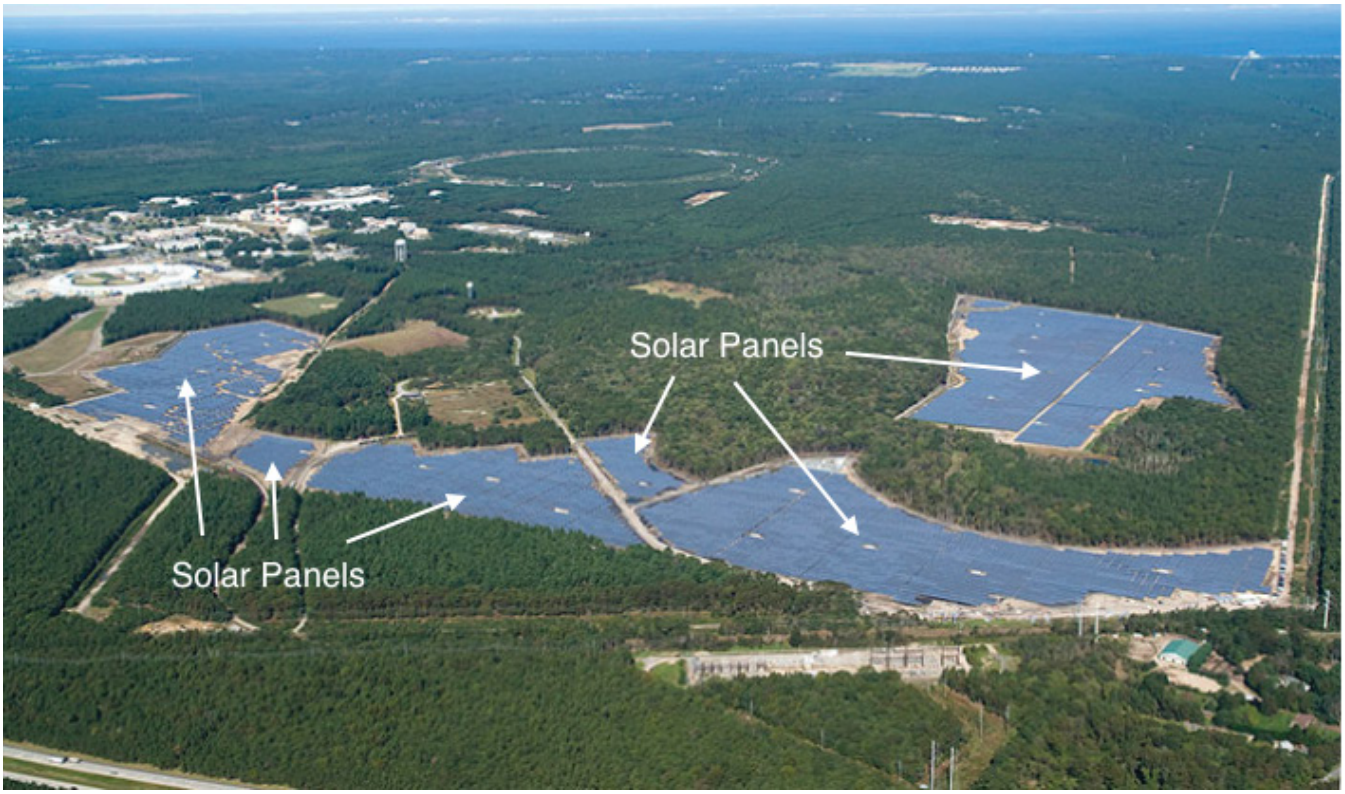

Figure 44. Long Island Solar Farm at Brookhaven National Laboratory (adapted from BNL, 2011).

to two shale gas multi-well pads. Figure 44 shows the 32 MW Long Island Solar Farm located at Brookhaven National Laboratory in New York State (BNL, 2011). As a point of comparison, the Deer Lake Power Plant (Kruger, n.d.) has a capacity of 129 MW of power and meets approximately 70% of the Kruger paper mill electric power requirements, which is the equivalent of at least four wind farms of the scale of the Laurel Hill Windpower Project or eight Long Island Solar Farm projects, assuming that the wind and solar farms operate at full capacity for 50% of the time.

Recent press reports document considerable public concern and opposition to some solar and wind farm projects as a result of potential land disturbance, as well as concerns about negative quality-of-life, environment, and health impacts (Schnurr, 2015) (Irving, 2015) (NWEM, 2015) (Hoggard, 2015) (Parker, 2015).

10.4 Common Themes from Public Opinion Survey and Submissions to the Panel

While the public opinion survey and the written submissions provided very different mechanisms for input to the process (i.e., answers to set questions versus open, free form input) and engaged different groups of individuals (i.e., random versus self-selected), there are common reasons articulated in the survey and the submissions with respect to support for, or opposition to, hydraulic fracturing in Western Newfoundland. Jobs and employment are agreed upon reasons in both the survey and the submissions for supporting hydraulic fracturing. Concerns about impacts on the environment, greenhouse gas emissions, quality of life, culture, water quality/contamination, unknown risks, absence of a social licence, decisions against hydraulic fracturing elsewhere, seismicity, health effects, impacts on wildlife/ecosystems, lack of trust in Government to regulate the industry, and Panel bias are common themes in both the telephone survey responses and the written submissions opposing hydraulic fracturing in Western Newfoundland.

11 SAFETY, RISK, AND RISK MANAGEMENT

11.1 Expectations about Safety

A request that the Panel received through the written submissions and the public consultation sessions was that the Panel recommend to Government that it *"ban fracking until scientifically proven safe"* (PPBSG, 2015) (Oliver, 2015). This request raises important questions about the notions of safety and risk and what they mean in the context of industrial activity, such as oil and gas operations generally, and hydraulic fracturing operations specifically. The Panel commissioned Dr. Faisal Khan, Professor and Vale Chair of Safety and Risk Engineering at Memorial University, to prepare a review of risk considerations relevant to hydraulic fracturing operations. Dr. Khan's report (Khan, 2016) is included as Appendix L of this report.

While there are risks associated with all human activity, the public expects that industry in the province operates safely from public health and safety, worker health and safety, and environmental protection perspectives. While loss of life, serious illness, and degradation of the environment are unacceptable outcomes from any industrial activity, incidents and accidents do occur.

In considering the prospect for a new industrial sector for the province, one expectation could be that the impact of the industry on public health and safety and on the environment would be comparable to other socially accepted industrial sectors already operating in the province. Another expectation could be that the performance of companies operating in a new industrial sector be at least on par with the best performers internationally.

11.2 What Is Risk?

There are costs and benefits with all industrial activity. As stated by the Institute of Risk Management, *"risk can be defined as the combination of the probability of an event and its consequences"* (IRM, 2002). In reference to health, safety, and the environment, discussions of risk generally deal with negative consequences, and the management of risk is focused on the prevention and mitigation of the harm. Appendix D includes a detailed explanation of the concept of risk and the need to consider both the probability and consequence of an event when assessing risk (Dusseault, 2016).

All human activity requires individuals and society to assume some level of risk. For example, driving an automobile includes risk of injury or death. While there are personal risk factors, such as personal decisions to drive on snow or ice with all-season versus winter tires or to drive while overtired, there are also more general risk factors associated with public highway infrastructure, such as divided versus undivided highways, highway lighting, ice control, and pavement conditions. Mechanisms to mitigate such general risks include setting and enforcing appropriate speed limits and designing roadways to include features that lower risk. For example, divided highways reduce the risk of head-on collisions. As with any significant investment of funds, the cost and benefits of investments to mitigate general risks must be considered. In the case of the Trans Canada Highway across Newfoundland, some of the highway is divided, presumably a decision made on the basis of some assessment of the benefits versus costs of the public investment needed to divide the highway.

Dusseault (2016) points out that *"the individuals responsible for a development, including the engineers and geoscientists who through licensure and legislation are expected to perform their work with a high degree of competence and ethics, have to identify the risks, delineate the probabilities and the consequences, and seek to mitigate the consequences and reduce the probabilities, as much as is reasonably achievable"*.

Appendix D goes on to state:

> *"What must be done if development is to be undertaken in Western Newfoundland is to encourage or mandate the investment of time, procedures and technology to reduce the risk to a level that is commensurate with the expectations of the resource owner (the people of Newfoundland through their different levels of government) and so that there is public confidence in proceeding with development"* (Dusseault, 2016).

Just as individuals have some tolerance for risks, both personal and general, arising from human activity, there is a public risk tolerance for industrial activity. The resource owner and stakeholder expectations noted in Appendix D reflect public risk tolerance that is typically predicated on effective regulation, comprehensive monitoring, and proactive application of best practices that mitigate risks and, to some extent, remediate damage that results from an accident or incident (Dusseault, 2016). For example, expectations with respect to public risk tolerance are implied in the submission by the City of Corner Brook, which reads (Corner Brook, 2015):

"If Government decides to proceed with hydraulic fracking we would suggest the following mechanism be established:

- *Conduct baseline testing of key environmental indicators before, during and after hydraulic fracturing activities, so that there is at least some clarity on whether changes have taken place. Such testing would in turn help identify whether current regulatory practices do in fact adequately mitigate environmental risks*
- *Develop exploratory regional regulations based on science*
- *Establish an Exploratory Regulatory Commission with a responsibility to ensure monitoring and compliance of the regulations*
- *Develop a Regional Economic Development Fund with a percentage of the royalties from oil and gas development being returned to the region*
- *Ensure adequate bond and insurance protections are in place in the event of environmental damage"*

Within a province such as Newfoundland and Labrador, there is a long history of natural resource development and of identifying, assessing, and managing risks in the context of an evolving level of public risk tolerance.

11.3 The Primary Environmental, Public Health, and Socio-Economic Issues

In the context of hydraulic fracturing operations, environmental and public health risks are described in various sections of this report and in the appendices. In some cases, both the probability of occurrence of an undesirable event and its consequences can be estimated and the associated risk could be quantified. In other cases, there is a fundamental knowledge gap that results in the probability and/or the consequences not being understood. If either the probability or the consequence is not understood, the risk cannot be quantified. There are risks associated with unconventional oil and gas development in Western Newfoundland that cannot be quantified at present because of the limited understanding of the Green Point shale geology. This limited understanding of the geology is highlighted in the Green Point Report (Hinchey, et al., 2014), Appendix J (Burden, 2016), and Appendix K (Eaton & Krebes, 2016).

The most recent comprehensive assessment of the environmental impacts of shale gas development in a Canadian context is found in the report for the Council of Canadian Academies (CCA, 2014). Environmental issues, along with social and public health issues, are also discussed in the reports of the independent reviews of hydraulic fracturing in Nova Scotia (NSIRPHF, 2014) and New Brunswick (NBCHF, 2016), as well as in research reports from the Canadian Water Network (CWN, 2015a). The Panel considered these issues in many of the appendices of this report, including Appendix D (Dusseault, 2016), Appendix F (Keough, 2016), Appendix H (Gagnon & Anderson, 2015), Appendix I (Husain, et al., 2016), Appendix J (Burden, 2016), Appendix K (Eaton & Krebes, 2016), Appendix L (Khan, 2016), and Appendix M (Lahey, 2016). These issues are also reflected in the public submissions to the Panel (Storey, 2015) and in the public opinion survey (MQO, 2015).

The primary environmental issues include:

- potential negative impacts on climate change over time from natural gas leakage resulting from the loss of well integrity due to poor quality cement seals on wells;
- possible stress on the capacity of local water supplies if these sources are to supply the water required for the completion of wells;
- a poor understanding of the local geology and the potential risks associated with the contamination of local drinking water supplies as a result of natural gas and saline water migration via complex underground pathways;
- possible contamination of surface water and groundwater sources from surface spills during transportation and from handling flowback and produced water, chemicals, and petroleum products;
- potential land disturbance and impacts on groundwater and surface water flow as a result of the construction of roads, well pads, pipelines, and other infrastructure required for unconventional oil and gas development; and
- possible earthquakes that may be induced during hydraulic fracturing operations.

The primary public health issues, many of which follow from the environmental issues, include:

- potential exposure to airborne toxicants arising from spills of fracturing fluids, wastewater, and petroleum products; leaks from wells; and emissions from large numbers of diesel trucks and equipment used during the development of wells;
- possible degradation in drinking water quality due to surface spills and migration of gas and chemicals;
- potential exposure to wastewater or other hazardous fluids as a result of accidents; and
- increased anxiety about potential health risks from the immediate and cumulative effects of industrial development, including effects from an increase in truck traffic, an increase in the likelihood of accidents, and an increase in noise.

The primary socio-economic issues include:

- possible increased stress on the healthcare and social services systems as a result of boomtown effects;
- potential negative impacts on other economic sectors, such as the fishery, tourism, and agriculture;
- possible negative effects on recreational uses of land and water;
- inadequate fire and emergency services in the region of development;
- potential major changes to the way of life in the vicinity of development as a result of the intensity of industrial activity, particularly during well construction;
- potential negative effects on Qalipu Mi'kmaq culture in the vicinity of development due to impact on the environment; and
- lack of confidence that Government can provide effective regulatory oversight of unconventional oil and gas development.

When considering these general issues or attempting to quantify the associated risks, it is important to take local context into account. This includes considering factors such as geology; geography; existing infrastructure; and existing emergency response, healthcare, and social services capacity. To date, there has not been a formal assessment of risks for prospective unconventional oil and gas development in Western Newfoundland.

As discussed in Appendix D, the local context is critical to both quantifying and managing risks. For example, Dusseault (2016) notes that:

> *"In these near-coastal regions of Western Newfoundland, the potable groundwater systems tend to be local and isolated one from the other, in contrast to wide-spread regional aquifers like in the Canadian Prairies; hence, even if a spill occurs, the impacts are much more local, isolated, and therefore manageable. The consequences are less, so the risk is less".*

As the case above illustrates, taking into account the isolated nature of the groundwater systems and by careful placement of well pads, the risk of a highly probable undesirable event (i.e., a spill) could be mitigated such that its consequence may be acceptable. Further mitigation is possible through regulations that require *"a multi-level groundwater monitoring well at each multi-well drilling site"* (Dusseault, 2016). The ongoing monitoring of such wells, including monitoring long after the producing wells are decommissioned, could help address concerns about leakages as a result of the loss of well integrity since *"a problem with energy wellbore integrity that impacts groundwater could be identified soon and corrective measures taken before a more severe problem develops over a larger area"* (Dusseault, 2016).

While environmental, public health, and socio-economic risks dominate public discussions about hydraulic fracturing operations, the discussions rarely consider the connected issues of the probability of an undesirable event, the mitigation options, and the consequences following mitigation, all of which are important to quantifying the risks.

11.4 Well Integrity Risk

Many of the concerns raised with the Panel about health and environmental risks are based on a fear that unconventional oil and gas wells are prone to a loss of well integrity. Such a loss of integrity could result in the migration of fluid into the near-surface layers, where water wells and land could become contaminated, or into the atmosphere as emissions that are harmful to humans and the environment. Loss of well integrity is discussed in detail in the literature and elsewhere in this report (CCA, 2014) (NSIRPHF, 2014) (NBCHF, 2016) (Dusseault, 2016) (CWN, 2015a) (Vengosh, et al., 2014) (Soeder, 2015) (Jackson, et al., 2013) (Davies, et al., 2014) (Dusseault, et al., 2014) (Ingraffea, et al., 2014).

The Council of Canadian Academies Panel states:

> *"Two issues of particular concern to panel members are water resources, especially groundwater, and GHG emissions. Both relate to well integrity. Many of the operational procedures used in shale gas extraction are similar to those used in conventional oil and gas extraction. Thus industry experience is relevant to understanding these issues"* (CCA, 2014).

As discussed in Geofirma (2014), the main issues of concern regarding long-term wellbore integrity include:

- *"emission of greenhouse gases (methane, perhaps a small amount of ethane); and*
- *entry of methane into the shallow aquifers where it may undergo geochemical deterioration and degrade the quality of the groundwater making it unfit for human consumption"* (Geofirma, 2014).

Furthermore, Geofirma (2014) goes on to state:

> *"Because the regulatory agencies do not require groundwater quality assessment and monitoring (using proper monitoring wells, although rural wells can give some useful information) nor surveillance of any abandoned wells after the abandonment guidelines have been met, the magnitude of the GHG emissions and the amount entering shallow aquifers are not known".*

While the loss of well integrity is not unique to unconventional oil and gas development, there are heightened concerns due to the large number of wells required for an unconventional oil and gas project, the nature of the chemicals used, the proximity of wells to domestic water supplies, and the effects of repeated fracturing of wells (CCA, 2014).

Appendix D (Dusseault, 2016) defines well integrity as *"integrity internal and external to the casing strings"* which serves to *"isolate the strata and prevent unwanted fluid flow either inside or outside of the casings during production and after decommissioning"*. Dusseault et al. (2014) include an extensive discussion about well construction and well integrity, while Appendix D considers these issues in a Western Newfoundland context.

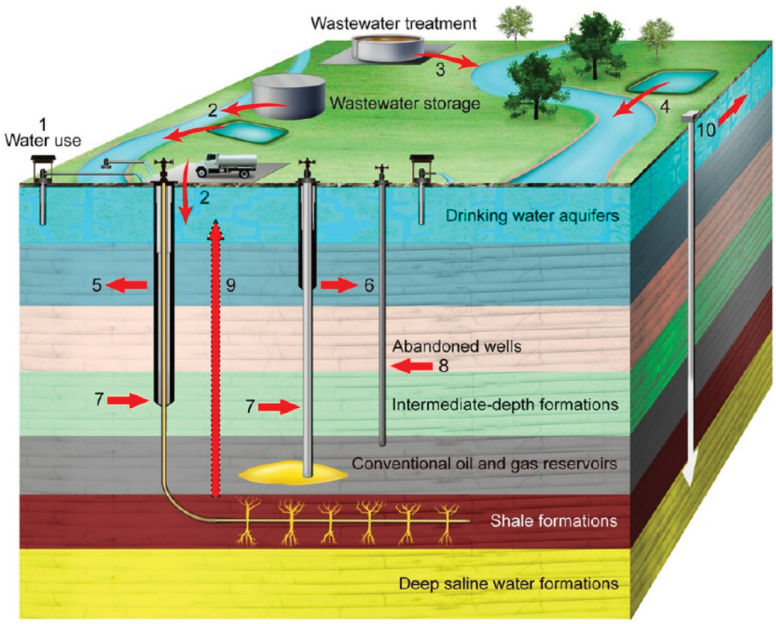

Figure 45. Illustration of potential pathways for contamination of drinking water aquifers (Vengosh, et al., 2014).

Figure 45 illustrates a number of potential pathways for contamination of drinking water aquifers, and groundwater more generally, as a result of hydraulic fracturing operations (Vengosh, et al., 2014). Most of these pathways are not unique to unconventional oil and gas wells, but also exist for conventional wells.

As discussed in Section 11.2, risk is a combination of the probability of occurrence of an event and the consequence of the event. As a result, the context of any specific development (e.g., proximity to other oil and gas wells, existence of abandoned wells, the proximity of wells to drinking water aquifers, depth of target formation, and containment redundancy on site) needs to be carefully considered when determining the actual risk of potential fluid leakage from wellbores.

The potential drinking water contamination pathways, which are indicated by the numbers 2-10 in Figure 45, include:

- Pathway 2: Spills from trucks transporting wastewater or chemicals, and wastewater or chemical storage facilities;
- Pathway 3: Spills or disposal of inadequately treated wastewater;
- Pathway 4: Leaks from wastewater impoundment ponds;
- Pathway 5: Leaks through the wellbore casing of hydraulically fractured wells of gas from the subsurface zone that has been fractured;
- Pathway 6: Leaks through the wellbore casing of existing conventional oil and gas wells;
- Pathway 7: Leaks of gas from the intermediate gas bearing zones into gaps in poorly cemented well casings;
- Pathway 8: Leaks of gas via abandoned oil and gas wells;
- Pathway 9: Migration of gas or fluids through upper geological layers from the subsurface zone that has been hydraulically fractured; and
- Pathway 10: Leaks from deep disposal wells.

As noted in Appendix D, of these pathways, *"by far the most common pathway for contamination is from the surface to the groundwater via spills, leaks, transportation accidents, and so on"* (Dusseault, 2016). Pathways 2, 3 and 4 are unrelated to the issue of long-term well integrity. Regulations and best practices for assessing, managing, and mitigating the risks and remediating impacts from surface spills and leaks are well developed and are discussed elsewhere in this report.

Deep disposal wells, as illustrated by Pathway 10, are common in Western Canada, where there are thick, porous, permeable, and un-deformed sedimentary beds that can take large volumes of wastewater and acid gas. At this time, it is not clear that deep disposal wells are a viable option in Western Newfoundland, where local sedimentary layers are thought to be deformed, of lower porosity, and probably dominated by fracture permeability. It is not likely that sites will be found that can accept large volumes of waste fluid injection (e.g., 1000-3000 m^3/day indefinitely) through vertical disposal wells. It is possible, however, that sites capable of small-scale injection (50-200 m^3/day) exist, perhaps even in parts of the Green Point shale. For example, if a suitable zone for wastewater disposal is found to exist in a layer above the target shale formation, a stratigraphic well may serve as a limited-volume wastewater disposal well. Any such zone must be able to accept such volumes without significant pressurization. Since these wells and the target formation are offshore and distant from any drinking water supplies, the Panel does not believe that there is any appreciable risk from Pathway 10.

Western Newfoundland has a limited history of oil and gas activity. There are only two existing wells that extend to the depth of the Green Point shale. Other wells in the region are shallow, vertical wells that are less than 300m in depth. Given that the locations of these wells are known and their histories are available, they would be easily accounted for during the planning of drilling and well stimulation. Also, as noted in Appendix J, the target shale for unconventional development in Western Newfoundland is offshore and *"beyond the reach of the older wells"* (Burden, 2016). Given the limited number of legacy wells and their known locations, the Panel does not believe that there is appreciable risk from Pathways 6 and 8 for legacy wells.

Pathway 9 corresponds to upward migration of gas and liquids from the shale formation that has been hydraulically fractured. For a variety of reasons that are discussed in more detail in Appendix D, the upward migration illustrated by Pathway 9 is not expected to be an issue for unconventional development of the Green Point shale (Dusseault, 2016). As noted in the Green Point Report (Hinchey, et al., 2014) and in Appendix J (Burden, 2016), the Green Point formation is not over-pressured. Attempts to produce oil from the existing conventional oil well at Shoal Point were not successful due to challenges with sustaining pressure and flow. Appendix J states that the data presented in the Green Point Report *"is simply a confirmation that downhole pressures are recording normal hydrostatic pressure"* (Burden, 2016).

Pathways 5 and 6 correspond to leaks of gas from within the wellbore through the steel casing. As discussed in Appendix D, in the context of Green Point shale resource development, there is low risk of loss of casing integrity as a result of the geological and operating conditions (Dusseault, 2016). For example, the low porosity of the Green Point shale means that it will be resistant to shearing, while low well pressure and small temperature variations reduce mechanical stresses on the casing that might lead to corrosion or cyclic expansion and contraction of the casing that could lead to loss of casing integrity.

Recent research has been published about the relationship between methane migration and shale-gas well operations in Dimock, Pennsylvania (Hammond, 2016), a town that featured prominently in the Gasland films (Gasland, 2015). This research, which employed molecular and isotope analysis to determine the origin of leaked gas, concluded that leaks resulted from gas migrating through poorly cemented seals or uncemented casing sections. Hammond (2016) also concluded that *"there was no evidence of leakage of Marcellus gases due to production casing failures"*. The paper also highlighted the importance of establishing baseline data for methane in water prior to well construction.

As discussed in Appendix D, Pathway 7, which corresponds to methane leaks arising from gaps in poorly cemented well casings, is *"of greatest concern, especially after well decommissioning when the inside-the-casing pathway has been plugged with several long cement plugs and mechanical packer seals"* (Dusseault, 2016). The primary issue is that cement shrinkage can allow gas pathways to develop behind the casings. Since gas is more buoyant than other subsurface fluids that could leak into the gaps in the cement, it can slowly seep to the surface or into shallow aquifers.

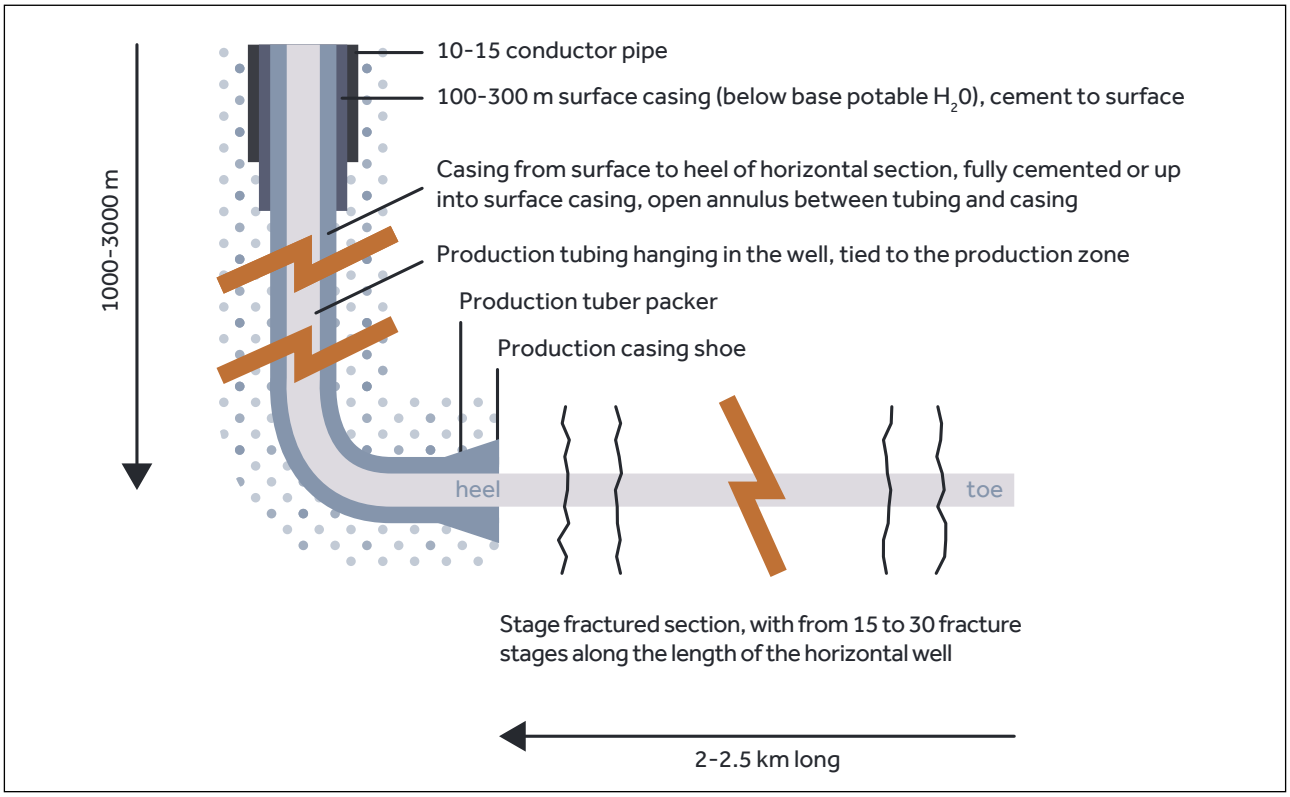

Figure 46. Illustration of well casing and cementing (Dusseault, 2016).

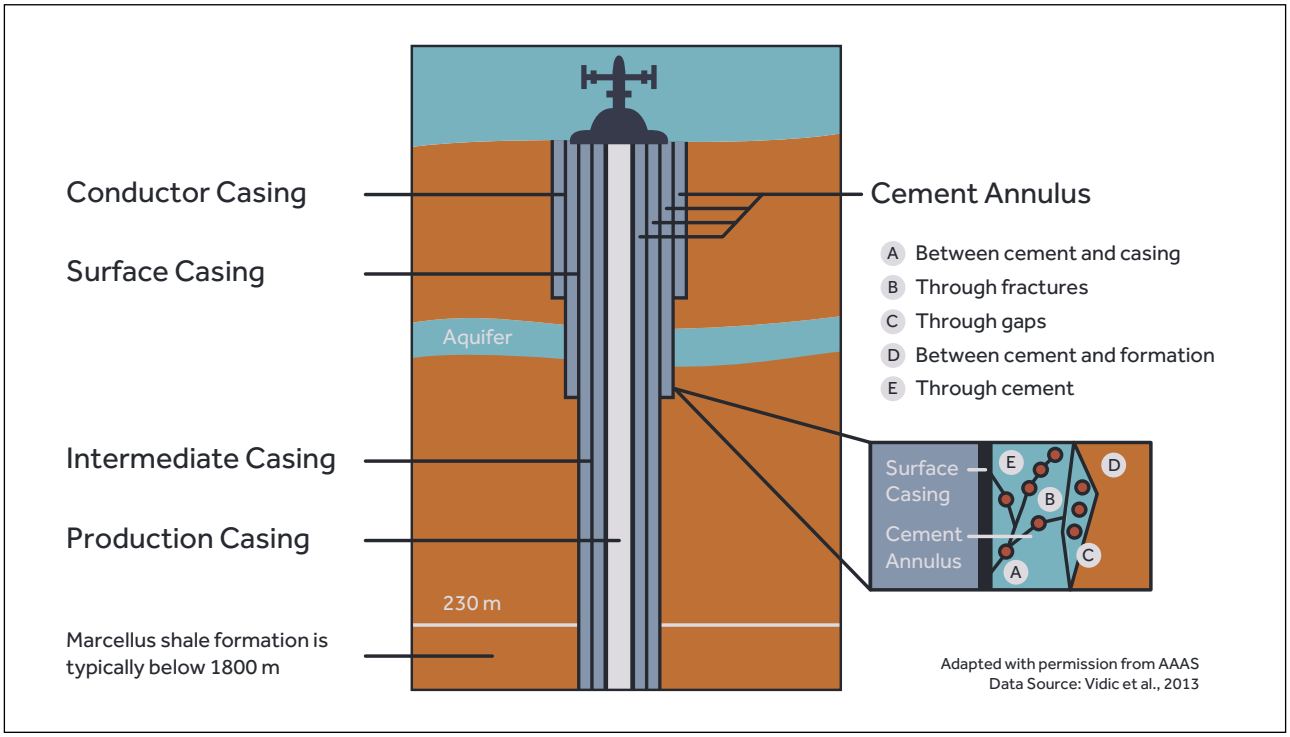

Figure 47. Illustration of the different layers of well casing and pathways for gas and fluid leakage (CCA, 2014).

Figure 46 illustrates the various layers of well casing and cementing for an oil well. Figure 47 illustrates how the set of steel casings are cemented in place in the wellbore and also illustrates the various pathways for leaks due to cementing problems.

Both short-term and long-term mechanisms lead to wellbore leakage (Dusseault, et al., 2014). The short-term mechanisms include improper drilling mud and cement slurry design, inadequate mud removal, and invasion of liquids and gases before the cement has set that result in pathways for gas migration. Long-term mechanisms include operating stresses (e.g., cyclic pressures and thermal stresses) from normal operation of a well, cement shrinkage, corrosion, and cement degradation. Other factors, such as the well abandonment method, subsurface geology, and type of well (e.g., vertical versus deviated), also affect wellbore leakage.

11.5 Approaches to Risk Management

While specific concerns about unconventional oil and gas development in Western Newfoundland are discussed in more detail elsewhere in this report, a short review of the frameworks or approaches to assessing and managing the associated risks is warranted. For the purpose of this report, three approaches to risk management are considered, including the Precautionary Approach, the "As Low As Reasonably Practicable" (ALARP) principle, and Adaptive Management.

Regardless of the risk management approach adopted for full-scale unconventional oil and gas development, the current pause on hydraulic fracturing operations in Western Newfoundland means that there are no data being collected nor studies being undertaken that would support a better understanding of the risks of development, many of which are contextual. As discussed in Appendix D:

> *"Recent moratoria on hydraulic fracturing in Nova Scotia (2014) and New Brunswick (2014), and the pause on accepting applications for hydraulic fracturing in Newfoundland (2013), have led to a substantial diminution of investments, and this also means that data generated from quantitative studies to support these investments that would allow a more quantitative risk evaluation of HC [hydrocarbon] development are no longer being collected in those jurisdictions. This makes the assessment process more lengthy, complex, costly, and with a greater level of uncertainty"* (Dusseault, 2016).

Within an industrial operation or across an industrial sector, one or a combination of risk management approaches may be employed, depending on the nature of specific risks to be managed.

11.5.1 Precautionary Approach

As discussed by the UNESCO World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), the Precautionary Principle (PP), or Precautionary Approach when considering its application, *"marked a shift from post damage control (civil liability as a curative tool) to the level of a pre-damage control (anticipatory measures) of risks"* (COMEST, 2005). Furthermore, as proposed by COMEST, the Precautionary Principle is applicable to problems that are characterized by *"(1) complexity in the natural and social systems that govern the causal relationships between human activities and their consequences and (2) unquantifiable scientific uncertainty in the characterization and assessment of hazards and risks"*. Specifically, a Precautionary Approach is indicated when:

- *"there exist considerable scientific uncertainties;*
- *there exist scenarios (or models) of possible harm that are scientifically reasonable (that is based on some scientifically plausible reasoning);*
- *uncertainties cannot be reduced in the short term without at the same time increasing ignorance of other relevant factors by higher levels of abstraction and idealization;*

- *the potential harm is sufficiently serious or even irreversible for present or future generations or otherwise morally unacceptable;*
- *there is a need to act now, since effective counteraction later will be made significantly more difficult or costly at any later time"* (COMEST, 2005).

Furthermore, COMEST goes on to state:

> *"Some form of scientific analysis is mandatory; a mere fantasy or crude speculation is not enough to trigger the PP. Grounds for concern that can trigger the PP are limited to those concerns that are plausible or scientifically tenable (that is, not easily refuted)"* (COMEST, 2005).

The Precautionary Approach has the objective of achieving lower and more acceptable levels of risks but *"is not based on 'zero risks'"*, a risk scenario that is not reflective of human activity (COMEST, 2005). The approach is not *"based on anxiety or emotion, but is a rational decision rule, based in ethics, that aims to use the best of the 'systems sciences' of complex processes to make wiser decisions"* (COMEST, 2005).

There exists some guidance as to when the Precautionary Approach is not the appropriate risk management approach. This includes *"when the scientific uncertainties can be overcome in the short term through more research, or when the uncertainties are simply understood as low probability of harm"* (COMEST, 2005). In addition, the Precautionary Approach is not appropriate *"when the harm is reversible and it is likely that effective counter-action is not becoming more difficult or costly, even when one waits until the first manifestations of the harm eventually occur"* (COMEST, 2005).

The Precautionary Approach *"is to supplement, but not necessarily replace, other management strategies that fall short of being able to handle large-scale scientific uncertainty and ignorance"*. Application of the Precautionary Principle does not necessarily mean a ban on an activity and "*a variety of possible precautionary actions may remain, ranging from simple restrictions upon a practice, strengthening the resilience of the system, the development of effective controlling (remediating) technologies, to a total ban of the activity"* (COMEST, 2005).

The Precautionary Approach may be implemented using more conventional risk assessment techniques. The U.K. Health and Safety Executive notes:

> *"Though the precautionary principle is invoked for hazards where, because of the uncertainty involved, it is not possible to apply the conventional techniques of risk assessment to assess the risks involved whatever the circumstances, it is possible in practice, to use such techniques for operationalising the principle"* (UKHSE, 2001).

The Precautionary Approach includes creating and evaluating credible safety cases or scenarios such that:

> *"Uncertainty is overcome by constructing credible scenarios on how the hazards could be realised and thereby making assumptions about consequences and likelihood. The credible scenarios can range from a 'most likely' worst case to a 'worst case possible' depending on the degree of uncertainty. For example, by assuming that exposure to a putative carcinogenic chemical will cause cancer the chemical becomes subject to a very stringent control regime"* (UKHSE, 2001).

There may be specific activities within hydraulic fracturing operations where the Precautionary Approach, including a ban, would be the appropriate risk management strategy. A decision to this effect should follow from a detailed risk assessment. For example, potential precautionary approaches to managing induced seismicity risk could include limiting the volume of water used to fracture a horizontal well, limiting or prohibiting the use of deep well disposal of wastewater, or prohibiting fracturing within a specific region.

11.5.2 As Low as Reasonably Practicable (ALARP) Principle

A common risk management framework that is utilized in industry is the "As Low as Reasonably Practicable" (ALARP) Principle, which *"requires operators to adopt a systematic approach to the identification of hazards and the application of quality engineered solutions and systems to develop the most effective techniques and approaches to best address those hazards"* (Precht & Dempster, 2014b). The ALARP principle originated in the United Kingdom and has been widely used for risk management in the context of safety-critical systems.

ALARP is not a prescriptive risk management approach, but one that leaves considerable latitude to the operator to use judgment in deciding on the approach to mitigate risks. The key element of the ALARP principle is the term "reasonably practicable", and this involves *"weighing a risk against the trouble, time, and money needed to control it"* (UKHSE, 2015). While the operator has latitude with respect to the choice of risk mitigation approaches, the ALARP principle requires the operator to weigh decisions in favour of health and safety. Where an operator is prepared to allow a risk to exist, there is a requirement for the operator to demonstrate that further risk mitigation *"would be grossly disproportionate to the benefits of risk reduction that would be achieved"* (UKHSE, 2015) .

The UK Health and Safety Executive states:

> *"The process is not one of balancing the costs and benefits of measures but, rather, of adopting measures except where they are ruled out because they involve grossly disproportionate sacrifices"* (UKHSE, 2015).

The ALARP principle looks to industry to propose what is reasonably practicable for a given risk scenario. Khan (2016) supports this as a reasonable starting point since *"industry best knows the technology, operating conditions, and limitations in given conditions"*.

While decisions about whether and how risks are to be mitigated appear to be left with the operator, as discussed in Appendix L:

> *"Risk tolerability in the ALARP principle is subject to social participation of people exposed to risks that may be imposed by projects undertaken by industry, government, or other agencies that are not under the direct control of the community. Public participation is a proper approach that can be used to determine risk tolerability with ALARP"* (Khan, 2016).

It is also important to understand that industry does not have the authority to decide on whether its risk mitigation strategy is "as low as reasonably practicable" (i.e., ALARP). In practice, third party verification and certification bodies are engaged to help develop or review risk management strategies. Furthermore, the regulator undertakes its own review and has ultimate decision-making authority with respect to deciding whether a proposed strategy satisfies the ALARP requirement.

The Irish Commission for Energy Regulation published an ALARP Guidance document, which draws on best practices in the UK and Australia (CER, 2013). This ALARP Guidance document provides insights into processes that may be employed in order to demonstrate that risks related to the petroleum industry have been reduced to ALARP. Within the discussion of implementation of the ALARP principle, consideration is given to situations where there is uncertainty with respect to the risks or the effectiveness of available risk mitigation strategies to be able to reduce the risk to ALARP. In such specific situations, the Precautionary Approach should be applied instead (CER, 2013). The ALARP Guidance document reads:

> *"Where there is reason to believe that serious danger could exist, but the scientific evidence is insufficient, inconclusive, or uncertain regarding the risk, then the petroleum undertaking [i.e.,*

company] is expected to apply the precautionary principle. In applying the precautionary principle, it is expected that a cautious approach is adopted to hazard management, commensurate with the level of uncertainty in the assessment and the level of danger believed to be possible" (CER, 2013).

11.5.3 Adaptive Management

The third approach to risk management that is important to consider in the context of unconventional oil and gas development is Adaptive Management (AM), which is a natural resource management approach that relies on learning by doing and adapting based on what is learned. It is an approach which brings together science and management in order to more effectively manage systems that are partially understood. Specifically, Rahm and Riha (2014) state:

> *"The AM [Adaptive Management] process is a structured, iterative decision making process that can be well suited for environmental management challenges in which decisions are made in the context of significant uncertainty, limited scientific experience, and conflicting agendas of multiple stakeholders"* (Rahm & Riha, 2014).

According to the US Department of Interior:

> *"Adaptive Management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process"* (USDOI, 2009).

The Marcellus Shale Lease Guide from the Pennsylvania Environmental Council, indicates that Adaptive Management is a best practice to be employed for all aspects of oil and gas activities being undertaken on leased lands in Pennsylvania (PEC, 2011). More specifically, the Guide outlines the following recommended practices:

- *"Require the oil and gas company to commit to employ current best management practices in all aspects of oil and gas operations. As technology develops and best management practices evolve along with technological and policy changes, require the oil and gas company to implement updated best management practices.*

- *Specify that when new laws or regulations are enacted regarding environmental impact or controls or technical aspects of oil and gas operations, oil and gas operations on the leased property must immediately comply with their terms.*

- *Require the oil and gas company to meet formally with the property owner at least once annually to investigate current laws and regulations, current technology applicable to Marcellus Shale gas operations, current best management practices, and environmental performance of oil and gas operations on the leased property since the last meeting.*

- *Require that current best management practices identified in the annual investigation be implemented immediately on the leased property."*

The key elements to successfully establishing an Adaptive Management framework (USDOI, 2009) include:

- effective stakeholder engagement;
- well-defined and understood management objectives;
- clearly identified management alternatives for actions to be taken at key decision points;
- effective models for assessing impacts over time; and
- comprehensive monitoring approaches, including baseline data collected in advance of development, that provide the necessary data and information for future decisions.

Once established, Adaptive Management is an iterative process that includes making decisions that reflect the current level of understanding and predicted future consequences, ongoing monitoring in order to evaluate decisions and to facilitate learning, and assessing management decisions including efforts to reduce uncertainty. The iterative process provides for a greater understanding of the factors affecting operations, the impacts of operations, and the effectiveness of management actions. The interactive nature of Adaptive Management allows for periodic reassessment of the key elements of the framework, and provides opportunities to review and improve upon the management objectives, management alternatives, and approaches to stakeholder engagement.

The potential for Adaptive Management to be an effective risk management approach for unconventional oil and gas activities depends upon some key conditions. As discussed by Rahm and Riha (2014):

> *"In order for AM-type strategies to successfully inform complex environmental policy and decision-making, they must generally involve certain steps, and conform to certain conditions: stakeholders and policy makers must be able to discuss and roughly agree on the risks or issues they are going to address; they must acknowledge the importance of governance; they must have or be willing to explore multiple management and regulatory options; they must have the authority, means, and capacity to monitor and evaluate the effectiveness of management and regulatory options once they are chosen; and they must have a willingness and mechanism for adapting and revising options in the face of new information"* (Rahm & Riha, 2014).

If there is no agreement among stakeholders regarding the risks that need to be better understood and managed, it is unlikely that Adaptive Management can be implemented successfully, since the parties are *"unlikely to be willing to invest resources in studying them [the risks]"* (Rahm & Riha, 2014).

If knowledge of the risks is incomplete, the stakeholders must be prepared to take measures to identify and understand these risks over time. The assessment of risks includes detailed consideration of the context for a particular situation. For example, the risk of vehicle collisions between private vehicles owned by the general public and vehicles used during hydraulic fracturing operations depends on whether hydraulic fracturing operations utilize public roadways. Currently, the understanding of risks associated with unconventional oil and gas development is *"biased towards the Marcellus shale, where a majority of peer reviewed studies have been focused"* (Rahm & Riha, 2014). Furthermore, the *"ability to extrapolate to other plays, regions, and countries is limited"*.

It is important to note that the results from studies initiated in other regions where unconventional oil and gas activity is taking place will help identify risks that are common across varying contexts. Closely monitoring the research results from such studies is important in implementing Adaptive Management. There remain, however, some risks that have a local context (e.g., climate, geology, geography, and development scenario) and which must be assessed with consideration to local conditions.

There is a significant up-front planning component to Adaptive Management, particularly for establishing baseline data and using this data, in combination with other information and knowledge, to develop initial policies and regulations. Successful implementation of Adaptive Management requires an investment in the up-front planning work. Relying on the revenues from unconventional oil and gas production to fund the planning costs only undermines the prospect for successful Adaptive Management. In the context of Marcellus shale gas activity, Rahm & Riha (2014) note:

> *"Revenues that might support such planning efforts are often derived from shale gas activity itself, meaning that money to hire adequate planners, inspectors, and scientists only comes after the activity they are meant to plan for begins".*

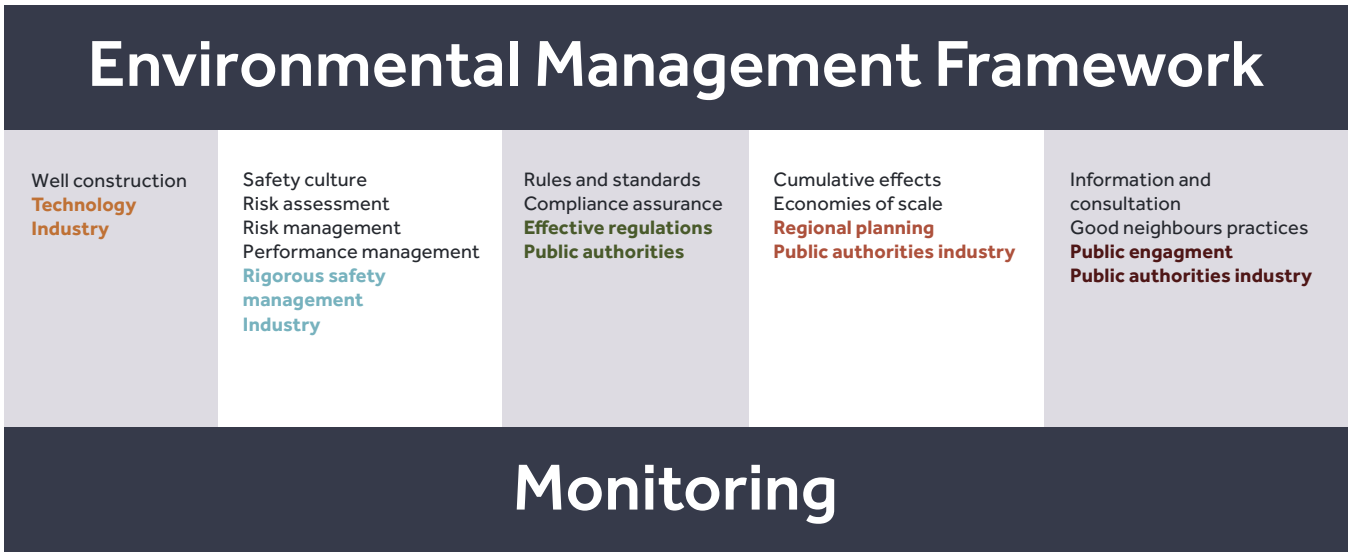

Figure 48. Environmental risk management framework proposed by the Council of Canadian Academies expert panel on the environmental impacts of shale gas development (adapted from CCA, 2014).

Figure 48 outlines an environmental risk management framework proposed by the Council of Canadian Academies Panel (CCA, 2014). This framework includes sound technologies, comprehensive management systems, an effective regulatory system, recognition of regional differences, and proactive public engagement. These elements are underpinned by a comprehensive monitoring program.

Within this framework, the elements are *"individually important and the absence of any one weakens the framework's effectiveness, making it vulnerable to unwanted events"* (CCA, 2014). In its conclusions, the Council of Canadian Academies Panel writes:

> *"Because shale gas development is at an early stage in Canada, there is opportunity to implement a variety of measures, including environmental surveillance based on research that will support adaptive approaches to management"* (CCA, 2014).

12 COMMUNITY ENGAGEMENT: PUBLIC CONFIDENCE AND SOCIAL LICENCE TO OPERATE

There are objectives for community engagement proposed in relation to a potential unconventional oil and gas development in Western Newfoundland (Precht & Dempster, 2014b). These include ensuring that:

- *"stakeholders understand the potential scope of the activity as a result of early and comprehensive disclosure of development plans;*
- *stakeholders are provided with timely, clear, and fair opportunities for engagement;*
- *industry processes provide stakeholders with opportunities to effectively engage in meaningful interaction and two-way communication;*
- *engagement efforts demonstrate understanding by industry and the regulator of local community and stakeholder concerns and how to best address those concerns;*
- *communication with stakeholders extends beyond traditional notification procedures to building productive relationships; and*
- *stakeholders have opportunities to provide input and express concerns about how the activity may affect their community".*

Increasingly for extractive industries, effective community engagement is critical to a new industry being established successfully and to its ongoing operations. There is a need for a shared understanding and a clear commitment from companies to incorporate community input and to respect community decisions with clear and public guidelines regarding consultation processes (Voss & Greenspan, 2012).

The Nova Scotia Independent Review Panel commented on the issue of community engagement:

> *"Public engagement regarding hydraulic fracturing must be substantial and should not be left to occur only between citizens and individual oil and gas proponents. If Nova Scotia was ever to permit hydraulic fracturing in the future, various publics must play significant roles in developing the regulatory process and so determining the rules and terms by which hydraulic fracturing can (and cannot) take place"* (NSIRPHF, 2014).

As discussed in Appendix M, effective community engagement involves more than fulfilling engagement obligations that are prescribed by regulatory requirements. Best practice requires community engagement *"that goes beyond obligatory consultations and that instead aims to achieve and sustain a deeply rooted social licence"* (Lahey, 2016). Community engagement should achieve *"alignment with community values and identification and maximization of the benefits to the community that development can bring"* rather than merely having the *"objective of reducing impacts*".

Although not explicitly mentioned in the Terms of Reference (NLDNR, 2014) for the Panel, throughout the consultation process the term "social licence" was frequently raised as a necessary condition for any development. References to social licence in the public submissions are mostly in the context of opponents to hydraulic fracturing stating that they believe that there is no social licence for hydraulic fracturing in Western Newfoundland. The issue of social licence is also discussed in a submission to the Panel by Shoal Point Energy (Shoal, 2015c).

The concept of a social licence was often undefined in the submissions to the Panel. Consequently, during the review process, the Panel sought clarification from individuals and groups that raised the issue of social licence in meetings or presentations to the Panel. Consistent with the diversity of perspectives in the literature, the feedback received by the Panel reinforced the lack of consensus with respect to the definition of social licence or the process by which a social licence could be gauged, achieved, or maintained. The feedback to the Panel is generally consistent with the conclusion by Quinn et al.:

> *"A social licence is an ambiguous concept. In our view, it stems from a long-term decline in the trust of government and industry to properly manage the technological and social risks for the public good"* (Quinn, et al., 2015).

The importance of a social licence in respect of potential unconventional oil and gas development in Western Newfoundland is also highlighted in the December 14, 2015 mandate letter from the Premier of Newfoundland and Labrador to the Minister of Natural Resources (Ball, 2015), which stipulates:

> *"You will ensure that any future decisions regarding the hydraulic fracturing industry are based on scientific evidence, and most importantly, on a social licence from the Newfoundlanders and Labradorians who may be affected".*

This mandate introduces an interesting blend of science-based and perception-based decision-making. On matters of scientific fact, the mandate letter highlights the need for the Minister to ensure that there are effective educational processes in place so that people, who will decide whether to extend a social licence, have the opportunity to make their decisions in view of sound scientific evidence and other information relevant to the Western Newfoundland development context. This scientific evidence and information must be presented in a balanced manner and not become an effort to persuade people toward a particular position, for or against development. Public education

must advocate for the facts about unconventional oil and gas development set within the context of Western Newfoundland. The Panel recognizes that, regardless of the scientific evidence pertaining to an issue, perceptions will be influenced significantly by the trust that individuals have in their sources of information. Also, some people or organizations holding ideological views, either for or against development, may not be interested in science-based information that does not support their positions.

The Panel decided to include social licence within its scope of work given that the concept was raised in the public submissions, that aspects of the concept fall within the scope of best practices in community engagement (Lahey, 2016), and that social licence is now a requirement of Government as outlined in the Minister of Natural Resources mandate letter (Ball, 2015). Consideration must be given to the level of public support for the type and scale of a specific development project by a particular proponent, such as the illustrative project described in Section 9 of this report. In advance of gauging public support for a specific project, however, there is a need to consider whether there is sufficient public support for Government to proceed with the necessary pre-development investments. Also, there must be support for the activities required to develop a better understanding of both the risks associated with development in Western Newfoundland and the approaches to mitigating those risks.

The concept of a social licence is widely discussed in the literature as a critical issue facing natural resource industries. This is also known as community consent, and *"around the world, local communities are demanding a meaningful voice in determining whether and under what conditions large scale oil, natural gas, and mining projects take place"* (Voss & Greenspan, 2012).

As noted by Oxfam, a social licence is not a static concept but rather reflects a relationship *"based on partnership and mutual respect"* (Oxfam, 2010). Communities are viewed as *"stakeholders with basic rights and real interests in the outcomes of extraction-related decision-making"*.

As noted by Canada's Public Policy Forum:

> *"A number of different terms have been used to refer to the growing impact of public opinion on development projects. From social license and social acceptance to community approval and public confidence, a range of terms is currently in use without commonly understood distinctions in meaning"* (PPF, 2015).

As mentioned previously, it is essential to secure public confidence, in addition to regulatory approval, for resource development projects to proceed. Obtaining such public confidence, however, involves challenges that, if not overcome, can undermine economic growth and associated improvements in the quality of life for many Canadians. There are, however, no universally accepted principles for securing public confidence, and this *"presents significant risks for industry and government"* (PPF, 2015).

Social media and the internet have broadened the discussion around specific development projects beyond local governments, project proponents, and communities. There is immediate access to a tremendous volume of information. A Google internet search in May 2016 using the keyword "fracking" resulted in approximately 12 million hits with no differentiation based on the credibility of information sources nor on the relevance of the resulting websites and content to any particular context for unconventional oil and gas development.

In general, organizations and groups opposed to unconventional oil and gas development have been more effective than industry in using the internet and social media to promote their positions regarding unconventional oil and gas development (PPF, 2015). Furthermore, governments have not played an effective role in facilitating balanced public education on matters related to unconventional oil and gas development. This is a prerequisite to meaningful and informed discussions about the risks and benefits of such development. More generally, a decline in public trust of government and industry, coupled with a limited understanding by the public of the public health, environmental, socio-economic, scientific, technical, and regulatory issues pertaining to a development project, heightens the challenge of securing public confidence.

The lack of a social licence is among the most significant business risks facing the international mining and minerals industry (Ernst & Young, 2015). Meaningful engagement by project proponents, including transparent and respectful interaction with the public and communities affected by a development, is critical to obtaining a social licence. Furthermore, Ernst and Young (2015) stresses *"the crucial importance of ongoing, regular and in-depth communication and engagement that exceeds basic regulatory requirements and cannot be underestimated"*. In addition, *"engagement from the prefeasibility phase is essential as is integration into the entire planning process to ensure that all stakeholders are aware of all impacts"* (Ernst & Young, 2015).

As discussed by the Public Policy Forum, *"public support requires a combination of legitimacy, credibility, and trust"* (PPF, 2015). Key elements of strategies to build and maintain public confidence and support include building relationships based on transparency and respect, advancing mutual benefits, and aligning efforts.

Factors leading to the establishment of a social licence, also known as "social licence to operate" or SLO, have also been considered in the context of case studies of international mining projects (Prno, 2013). As noted by Prno (2013):

> *"A SLO was said to exist if broad community approval and acceptance had been issued for the mining project in question. However, it should be noted no formal licence or contract is ever actually granted by a community. Rather, a SLO is a largely intangible agreement that a mining project should proceed, secured through a process of ongoing negotiation with local stakeholders".*

Prno (2013) goes on to state:

> *"As a general rule of thumb, a SLO was considered 'issued' when at least a majority approval and acceptance of a project appeared to exist ".*

Based on case studies of mining projects in Canada, USA, Peru, and Papua New Guinea, the key factors that underpin the establishment of a social licence include (Prno, 2013):

- context;
- relationships;
- sustainability;
- local benefits;
- public participation; and
- adaptability.

In terms of context, community-specific issues are most important (Prno, 2013). For example, *"What are the goals of the community and what forms of development do they aspire towards?"* Also, past experiences with proponents of development projects shape present perceptions of future developments.

Building and maintaining relationships are key to gaining a social licence, and companies must be *"a trustworthy, respectful, community-minded entity"* (Prno, 2013). It is also critical to develop relationships with the right people. The community at large must be engaged and not only politicians or those *"who are the most outspoken"*. Key community stakeholders must be identified and appropriate engagement strategies employed to develop positive relationships. The leadership and commitment from senior employees of the proponent are also important to gaining a social licence.

The case studies highlight the importance of sustainability to the communities involved in a prospective development. The communities' own view of what sustainable development means is more important than some external definition and it is *"only when a community feels their vision of social, economic, and environmental sustainability is being supported, or at the very least isn't being threatened, will they begin to contemplate issuance of a SLO"* (Prno, 2013).

With respect to local benefits provision and public participation, it is not merely a case of companies complying with *"formalized mechanisms to distribute benefits (e.g. legal and regulatory instruments, Impact and Benefits Agreements)"* (Prno, 2013). Regardless of formalized mechanisms to distribute benefits, perceptions of insufficient local benefits can lead to the erosion of a social licence. There is a need for *"public participation in decision-making, access to information, and access to justice"*, and the most effective form of engagement will depend on the particular groups that are involved.

Finally, recognizing that establishing and maintaining a social licence is a complicated process, adaptability is needed to be able to deal with complexity (Prno, 2013). The process must adapt to local context and to local sentiments toward a development project that evolve and change with circumstances. In some cases, the willingness of a community to maintain a social licence could be influenced by circumstances beyond the control of the proponent. Adaptive approaches to community engagement are important to the process of maintaining a social licence.

In its final report, the New Brunswick Commission on Hydraulic Fracturing stressed the importance of engagement with the community that is built on trust and mutual respect (NBCHF, 2016). In this report, the importance of the relationship between the affected communities and the government that has the authority to approve a development is highlighted. The New Brunswick Commission concluded:

> *"Conversations regarding hydraulic fracturing and shale gas must be community-focused because it is the communities located closest to proposed and existing developments that accept the most direct risk if Government decides to proceed. ... At its core is a recognition that the Government's relationship with residents is built on trust and mutual respect"* (NBCHF, 2016).

This sentiment is consistent with the conclusions of research supported by the Canadian Water Network that *"governments must discover better ways to bring different interests together to produce common shared-objectives that have general support"* (Quinn, et al., 2015).

Moffat & Zhang (2014) considered the concept of a social licence in the context of mining operations, but noted that the issues are applicable to other extractive industries, such as oil and gas. Trust between a community and a proponent is central to the notion of social licence and is a *"strong predictor of community acceptance of its [the proponent's] operations"* (Moffat & Zhang, 2014).

Furthermore, Moffat & Zhang (2014) stated:

> *"The extent to which a mining company manages and mitigates operational impacts (e.g., impacts on social infrastructure) will affect trust in the company. In particular, the way companies engage with communities (i.e., the quantity and quality of contact) and treat community members (i.e., procedural fairness in this relationship) will shape community members' trust in a mining company, and thus their acceptance of its mining operation".*

Frequent and meaningful interactions between operating companies and the communities most directly affected by a development project characterizes, in part, the trust relationship between the communities and the companies. A trust relationship is established when communities understand that they are being treated fairly by the companies in decisions related to a development.

As part of its mandate, the New Brunswick Commission on Hydraulic Fracturing (NBCHF, 2016) was asked by the Premier of New Brunswick to advise whether a social licence to proceed with hydraulic fracturing existed in New Brunswick. Early in its work, the Commission prepared a working definition of social licence to mean "informed public consent" with the following interpretation (McLaughlin, 2015):

- *"Informed – this reflects the need for an open and transparent process that provides everyone with access to timely scientific and technical information, delivered by trusted and objective sources, and that also has the ability to bring all parties together for a meaningful shared dialogue about the possible risks and benefits of a project;*

- *Public – reinforcing the central role of citizens in this process and the responsibility we each bear to participate – and the responsibility of government to create an environment that enables that participation; and*

- *Consent – reflecting the need to build trust in the public engagement and regulatory processes".*

This working definition of social licence closely follows the principle of Free, Prior and Informed Consent (FPIC), as described by IPIECA, the global oil and gas industry association for environmental and social issues (IPIECA, 2016). The elements of FPIC are:

- *"Free – people are able to freely make decisions without coercion, intimidation or manipulation;*
- *Prior – sufficient time is allocated for people to be involved in the decision-making process before key project decisions are made and impacts occur;*
- *Informed – people are fully informed about the project and its potential impacts and benefits, and the various perspectives regarding the project (both positive and negative); and*
- *Consent – there are effective processes for affected Indigenous Peoples to approve or withhold their consent, consistent with their decision-making processes, and that their decisions are respected and upheld".*

In a submission to the Panel, Mr. Wayne Hounsell presented a practical interpretation of social licence (Hounsell, 2015). This practical interpretation is also broadly consistent with the IPIECA's FPIC interpretation (IPIECA, 2016) and with the New Brunswick Commission's working definition (McLaughlin, 2015) of social licence.

The Panel understands the requirements proposed in Hounsell (2015) to mean that communities must have:

- clear and adequate knowledge, based on independent scientific research;
- an ability to make an informed decision based on all of the implications;
- an ability to communicate directly with government and industry in a meaningful discussion as to the values of the project; and
- an ability to say "yes" or "no" to a project.

In reference to the work of the Panel, Hounsell (2015) concludes that *"this public consultation is not an exercise in social licence"*.

The interpretation proposed by Hounsell (2015) further illustrates the need for increased knowledge by the public based on independent, science-based research; the need for open and meaningful communication among communities, government, and industry; and the requirement for communities affected to have public confidence in, and be supportive of, development. The interpretation, however, does not deal with issues related to maintaining the social licence once a development is underway.

A somewhat different view of social licence is included in a submission to the Panel by Shoal Point Energy (Shoal, 2015c), which suggests that the term social licence was originally associated with *"how to operate in international jurisdictions with a weak rule of law"*, while within Canada *"it is widely associated with consultation and accommodation of First Nations"*. The lack of consensus with respect to the definition of social licence and the lack of clarity with respect to how to gauge whether it has been achieved and maintained are also noted (Shoal, 2015c). Concerns are also expressed that the vagueness and lack of consent around the definition of social licence are used by opponents of projects to give them authority to claim that a "social licence has not been met".

Mr. Brian Lee Crowley of the MacDonald-Laurier Institute also articulated similar concerns. In a recent interview with the CBC, he described the one-sided use of the social licence concept by *"people who are opposed to development per se"* (Crowley, 2015).

Crowley (2015) stated:

> *"There is nothing you can say, there's no form of compensation, there's no kind of negotiation you can engage with them on that will win their consent to the projects. They are simply using the idea of social licence to say, 'Look, as long as I'm opposed to this project, you don't have social licence'".*

Dr. Dwight Newman, Professor of Law and Canada Research Chair in Indigenous Rights in Constitutional and International Law at the University of Saskatchewan, cautioned:

> *"To put it bluntly, any overly enthusiastic embrace of social licence to operate in its mistakenly transformed senses is actually a rejection of the rule of law and a suggestion that Canada should become a less well-ordered society"* (Newman, 2014).

Despite concerns about how the concept of social licence has been distorted, Crowley (2015) stated:

> *"You've got a perfectly legitimate sense in which social licence is used – and that's the sense it's a calm, cool, rational, risk, and reputation management by project proponents, governments, communities and so on, in which we seek, as a civilized society, to get the consent of communities to carry out large projects".*

It is under such conditions that the concept of social licence converges with best practices in community engagement which, as discussed in Appendix M, may be reflected in progressive regulations and oversight processes falling within, rather than outside of, democratic processes (Lahey, 2016). As discussed by Quinn et al. (2015), there is a need for *"public spaces essential for democratic discourse about hydraulic fracturing"*. Furthermore, Quinn et al. go on to state:

> *"Leaders must be motivated and government-societal structures must facilitate the creation of different kinds of public spaces and opportunities to exchange information across communities, policy sectors, and jurisdictions"* (Quinn, et al., 2015).

With respect to the statement by Hounsell (2015) that *"this public consultation is not an exercise in social licence"*, the Panel is in full agreement that the public consultation sessions, and the review process followed by the Panel, more generally, is not the basis for granting a social licence. The Panel hopes, however, that the discussion in this report about the concept of social licence, along with the recommendations related to community engagement in Section 14.2.1, are useful to Government in formulating a mechanism to address the obligations with respect to social licence outlined in the Minister's mandate letter (Ball, 2015).

The Panel also hopes that this report, including the documents in the appendices, serves as a foundation for building a repository of accurate and balanced public information about unconventional oil and gas development in the context of Western Newfoundland. In this respect, the work of the Panel may be helpful in raising the level of public knowledge in advance of Government determining, as stated in Ball (2015), whether there is "*a social licence from the Newfoundlanders and Labradorians who may be affected"* by a development.

13 PRIMARY RECOMMENDATION OF THE PANEL

13.1 The Recommendation

Returning to the primary task of making a recommendation on *"whether or not hydraulic fracturing should be undertaken in Western Newfoundland"* (NLDNR, 2014), the Panel does not believe that a simple yes or no answer would be appropriate or responsible, especially given the unknown and unresolved issues. The Panel, however, unanimously recommends that a number of gaps and deficiencies must be addressed before the necessary conditions could exist that would allow for hydraulic fracturing, as an all-inclusive industrial process, to proceed reasonably and responsibly in Western Newfoundland.

The issues identified by the Panel encompass provincial and regional policy and planning shortcomings related to energy and climate change policies, regional economic development plans, social wellbeing, health status and protection, environmental protection, and the regulatory environment. In addition, there are knowledge gaps of both a scientific and technical nature. For unconventional oil and gas development to be permitted in Western Newfoundland, there must be an understanding by the public of the scale of such development and what it means to individuals and families, the region, and the province. Furthermore, there must be a clear understanding of the corresponding benefits and risks. There also needs to be public confidence in the actions taken to address the issues.

If an unconventional oil and gas industry is to be established in Western Newfoundland, industry must be able to engage in the exploration, development, and production of unconventional oil resources with confidence that there is a clear "path to profit." This would include clarity about the process to be used by the Minister to determine whether there is a social licence.

The Panel recommends, at this point, the "pause" in accepting applications involving hydraulic fracturing in Western Newfoundland should remain in effect while some of the supplementary recommendations described in Section 14 are implemented. The supplementary recommendations represent a cautious, evidence-based, and staged approach that should facilitate a better-informed decision with respect to whether hydraulic fracturing operations should be permitted in Western Newfoundland.

13.2 The Rationale

While other opportunities may exist in Western Newfoundland to utilize hydraulic fracturing operations, at the present time, and based on the information provided to the Panel through the review process, only the Green Point shale resource has been given significant consideration. Based on the review, the Panel is of the opinion that the Green Point shale represents an unconventional oil and gas resource that could, depending on oil prices and other considerations, be of economic value to Western Newfoundland. This value could be realised through employment and business opportunities arising from development and through a revenue sharing model that favours the local area. For communities near Stephenville and around the Port au Port Peninsula, the economic value could be important in the near-term (i.e., for one or two generations) for sustaining communities in the region. For the longer term (i.e., several generations), Western Newfoundland needs an economic development plan that defines socio-economic approaches to sustaining the region as a place for people to live, work, and make homes for their families and their children's families. Commercial exploitation of the Green Point shale resource may offer an opportunity that helps the Stephenville-Port au Port region bridge to a more economically diverse and sustainable future.

It is the view of the Panel that the Green Point shale is not a regional or provincial energy resource that is critical to the province meeting its short-term or long-term energy requirements. Exploitation of the Green Point shale, however, may be a valuable opportunity for regional economic development around the Stephenville-Port au Port area. In this context, the primary issues are (1) whether the economic benefits that could accrue through the exploitation of the resource would outweigh the short-term and long-term costs of such development, and (2) whether the province and, in particular, the people most affected by development, are prepared to accept the cost-benefit trade-offs.

It is an open question whether the development of the Green Point shale represents an opportunity to undertake a relatively small, short-term development project (e.g., limited to 150 million barrels), to initiate a somewhat longer-term and larger development project (e.g., growing to 450 - 900 million barrels), or to lay the foundation of a multi-project industry (e.g., several billion barrels) that carries on for many years at different locations in Western Newfoundland. Based on what is known at this point, the Panel does not believe that, as an individual project, development of the Green Point shale would be a significant component of the province's economic future.

It could be argued that, in view of the province's short-term economic outlook, each region of the province needs to capitalize on every opportunity for economic growth and new employment. As discussed in Section 14, unconventional oil and gas development of the Green Point shale will require a number of significant public expenditures well in advance of a decision whether to proceed with a full-scale development. In effect, Government must decide whether the potential economic and employment returns on the public expenditures offsets the risk that these may not be realized if development does not proceed. Furthermore, Government must decide if the potential returns are more favourable when compared to returns from a similar level of public expenditure to stimulate other industrial opportunities in the region or elsewhere in the province. Decisions in the short-term are complicated by the impact of low current oil prices on provincial revenues and, in turn, on the ability of Government to make the necessary expenditures.

From an economic perspective, the analysis of the illustrative project to develop part of the Green Point shale resource showed that the project is not viable at mid-2016 oil prices (i.e., approximately $49 US per barrel on May 16, 2016). The economic and fiscal analyses also indicated that the project is not attractive below an oil price of $85 US per barrel.

As with all industrial activity, there are benefits and risks associated with unconventional oil and gas development that need to be identified, understood, and evaluated. Should unconventional oil and gas development proceed in Western Newfoundland, the Panel believes that the risks must be identified and managed to ensure the health and well-being of the people and to protect the environment.

Although exploitation of unconventional oil and gas resources, such as the Green Point shale, requires the use of hydraulic fracturing operations, techniques and technology are evolving and improving, as are the regulations and practices in jurisdictions where industry has been operating for a number of years. Reflecting on past practice, the Council of Canadian Academies Panel comments that *"some previous shale gas development practices that are no longer acceptable today have left some environmental impacts and negative influence on public opinion"* (CCA, 2014).

As summarized in Appendix N, numerous submissions to Panel raised concerns about public health and environmental risks (Storey, 2015). Members of the Panel and experts engaged by the Panel explored these risks and approaches to their assessment and mitigation in more detail in the appendices to this report. As noted in Appendix F, public health benefits might accrue in the near-term and medium-term through gains in income to individuals and communities emanating from employment and revenue sharing opportunities (Keough, 2016). These health and environment impacts will be better understood as more information becomes available from research ongoing elsewhere and from longitudinal studies that the Panel expects to be undertaken within jurisdictions where hydraulic fracturing operations have been established. These studies are important for a better understanding of the risks of unconventional oil and gas development, and for further improving regulations, practices, and technologies to deal effectively with the issues identified.

While some of the risks and mitigation approaches may be better understood through studies and advances in regulations, practices, and technology in other jurisdictions, the Panel feels that there are particular local issues (e.g., geology, geography, health and environment baselines, health impacts, regulatory environment, civil infrastructure and service impacts, regional economic and community plans, public knowledge, and public confidence) that need to be understood and evaluated by Government prior to making a decision whether to permit development. It is

important to appreciate that these local issues, for which context is important, cannot be addressed by relying solely on studies from other jurisdictions. In particular, additional studies and assessments specific to a prospective Green Point shale development, or any other future development, are necessary.

Within the Newfoundland and Labrador context, the Panel believes that there are significant gaps in provincial policy and regional planning related to unconventional oil and gas development in Western Newfoundland. Specifically, the province's Energy Plan, Climate Change Action Plan and Regional Economic Development Plans for Western Newfoundland are currently silent on the role of unconventional oil and gas development. Deficiencies with respect to critical baseline data about public health and the environment exist, as do deficiencies in the fundamental understanding of the geology of the Green Point shale, the only potential resource that the Panel is aware is under serious consideration for development using hydraulic fracturing technology.

The Green Point Report (Hinchey, et al., 2014) and the commissioned geoscience reports (Burden, 2016) (Eaton & Krebes, 2016) highlight fundamental geoscience knowledge gaps that need to be addressed prior to considering an industry-led exploration program. The necessary background geoscience knowledge may be gained through a combination of enhanced seismicity monitoring and assessment in the region, as well as improved seismic imaging, drilling, core sampling, and analysis of the resource that would lead to a better understanding of the local geology. With this enhanced understanding, it should be possible to determine whether further exploration is appropriate and the form that such an exploration program should take.

Of concern to the Panel is the limited understanding of the risks, benefits, and scale of development. The public has educated itself through sources of information on the internet and through presentations by individuals or groups with either pro-development or anti-development perspectives. The City of Corner Brook noted that *"as a Council we are listening to arguments from all sides"* and *"there are a lot of conflicting arguments and debates"* (Corner Brook, 2015). The Town of Kippens stated *"in conclusion, it would be fair to say that the Mayor and Councillors of the Town of Kippens have not been provided with enough evidence-based information to make an informed decision on whether or not hydraulic fracturing would be more of an economic benefit as opposed to an environmental risk on the Port au Port Peninsula"* (Kippens, 2015). A conclusion from a Harris Centre forum held in Western Newfoundland in February 2015 was that *"as regards to fracking itself, there is a need for more information about it in order to be able to make an informed decision about its possible adoption in the region"* (Harris, 2015b).

Perhaps most significantly, the Panel believes that there is not an understanding of the scale of hydraulic fracturing operations that would be required for commercially viable exploitation of unconventional oil and gas resources. There is neither an understanding about how an industry would scale-up its activities through exploration, development, and production phases of operations, nor is there an understanding of how those activities could impact the day-to-day lives of individuals living near such operations.

As noted in its submission to the Panel, the Qalipu Mi'Kmaq First Nation Band recognizes the need for community leaders to gain knowledge about hydraulic fracturing and to bring this back to their communities:

> *"We, as an organization, set out to actively research hydraulic fracturing, talk to stakeholders and better understand the process of hydraulic fracturing so that we can ensure to ask the right questions, and provide accurate information to our membership. Though this, we will be able to provide the resources required to our membership to be able to make informed decisions, and formulate founded opinions on various aspects of activities surrounding hydraulic fracturing"* (Qalipu, 2016).

The Panel believes that unconventional oil and gas development in Western Newfoundland, at least initially, would focus around Port au Port Bay and the Green Point shale. During the development phase, when wells are being drilled and put into production, the level of industrial activity on the Port au Port Peninsula could transform the day-to-day lives of the people living in the area. This will be primarily through truck traffic during the construction of wells

and associated infrastructure, unless alternative approaches to the movement of materials are utilized. Such a development phase could last from 5-10 years, as up to 500 wells could be constructed at approximately 30-40 on-shore sites around Port au Port Bay. Further details of an illustrative scenario for full-scale unconventional oil and gas development in the Port au Port region are discussed in Section 9.

In contrast, expansion of conventional oil and gas production, such as that carried out offshore Newfoundland at Hibernia, often involves the addition of a small number of wells. The recovery estimates for Hibernia increased since production began in 1997, when the estimated recoverable reserves were 520 million barrels and the platform included approximately 30 production wells. Today, the estimated recoverable reserves are in excess of 1.6 billion barrels, and Hibernia, including the Hibernia Southern Extension, includes approximately 40 production wells, which may increase to 50-60 before production is completed. For unconventional oil and gas development of the Green Point shale, it is expected that any significant increase in recoverable oil will require a proportional increase in the number of wells since each well only collects the oil that flows from the fractured shale near the wellbore. Any significant increase in the size of a project, or the development of an industry with multiple projects, will result in a corresponding increase in construction activity and the associated impacts discussed in this report. A benefit of a significant expansion to a project or to the development of an industry based on multiple projects is that it could provide an opportunity to develop a base of local skills and expertise. With this base, it would be possible to retain a much greater share of the construction-phase employment in the region if an industry, rather than a single project, were to develop. If unconventional oil and gas development in Western Newfoundland is limited to the Green Point shale project on the scale discussed in Section 9, much of the skilled employment required during construction will be imported into the region and likely will leave once construction is completed.

If unconventional oil and gas development is to proceed, public confidence must be achieved and maintained. On matters related to development in Western Newfoundland, public confidence in industry and Government currently appears to be low. This low public confidence contributes to the lack of public support for unconventional oil and gas development expressed through the review process. Based on the input received by the Panel, including the results of the public opinion survey (MQO, 2015) and the survey by the Qalipu Mi'Kmaq First Nation Band (Qalipu, 2016), there is no evidence to indicate that a social licence, where that is taken to mean general public support, exists for unconventional oil and gas development in Western Newfoundland. The required pre-condition for a social licence, that being an understanding by the public of unconventional oil and gas development, including the scale, the risks, and the benefits, does not currently exist. Given that perceptions of public health and environmental risks influence public confidence, it is important that there be convergence between actual risks and perceptions of risk. The Panel feels that this convergence will only be possible if risk assessments and the risk management framework for a project employ best practices in community engagement. While it is important for decision makers to *"have robust frameworks to evaluate these uncertainties"*, Quinn et al. go on to say:

> *"However, much of the critical decision making will need to make sense of the 'messy' world of societal beliefs and values. In particular, understanding and communicating about risk and uncertainty is essential. It is a mistake to believe that the facts will speak for themselves"* (Quinn, et al., 2015).

13.3 A Way Forward to a Better-Informed Decision

The Panel believes that there is a way forward that would allow for better-informed consideration of whether hydraulic fracturing operations should be permitted in Western Newfoundland. The first step is to consider unconventional oil and gas development in the context of up-to-date and forward-looking provincial policies and regional plans in which there is public confidence.

Next steps must also include a comprehensive evaluation of the risks and benefits of development. In addition, basic geoscience research, including experiments and field testing, is required to understand the Green Point shale resource and the technical risks of full-scale development of that resource. An effective regulatory system

and appropriate risk management approaches would help ensure that unconventional oil and gas development in Western Newfoundland, should it proceed, will be carried out in a manner that supports public health, protects the environment, and maintains confidence of the people most affected by a development. The way forward is predicated on a comprehensive and balanced program of public education.

Since Gros Morne National Park is adjacent to the Green Point shale resource, clarity with respect to how development potentially affects the Park is important. Restrictions on development around the Park will limit the amount of oil and gas that might be recovered from the Green Point shale, with an impact on the economic and fiscal analyses for a project. There are concerns that industrial activity around Gros Morne National Park could threaten its designation as a UNESCO World Heritage Site or could negatively impact the enclave communities around the Park that have developed a tourism industry based largely on Gros Morne. An appropriate buffer zone around Gros Morne National Park must be established.

The Panel believes that better-informed decision-making by all stakeholders, including Government, the public, and industry, is the "way forward". In particular, the Panel feels that the supplementary recommendations presented in Section 14 outline a process to give full and fair consideration to unconventional oil and gas development in Western Newfoundland and to provide a better foundation for a decision about whether such an approach to oil and gas development should be permitted.

14 SPECIFIC RECOMMENDATIONS OF THE PANEL

The Panel presents supplementary recommendations as advice to the Minister about actions to be taken if further consideration is to be given to permitting unconventional oil and gas development in Western Newfoundland. Except where explicitly noted, the Panel believes that the responsibility for implementing the recommendations rests with Government. In some cases, the supplementary recommendations create expectations and obligations for the regulator and for project proponents.

The supplementary recommendations are colour-coded (**'red stage'**, **'yellow stage'**, or **'green stage'**) to indicate the sequence in which they should be implemented. In some cases, supplementary recommendations have decision-gates, designated by "?". The implementation of recommendations that include decision-gates could lead to a determination that, from a public policy, public health and safety, environmental, socio-economic, or fiscal perspective, the "pause" in accepting applications involving hydraulic fracturing in Western Newfoundland should remain in effect, or that restrictions on specific activities might be imposed.

The Panel feels strongly that in acting on the supplementary recommendations in this report, Government should use a transparent, robust decision-making framework that includes a roadmap for the actions arising from the recommendations, the time-frame for such actions, and definition of the roles to be played by various stakeholders. By being open, transparent, and inclusive of key stakeholders, Government has the opportunity to build public confidence in the actions and in any subsequent decisions.

The **'red-stage'** supplementary recommendations describe actions, primarily related to public policy and processes, that the Panel feels must be undertaken before the "pause" can be lifted. These recommendations include:

- identify, adopt, and demonstrate best practices in community engagement;
- create and implement an ongoing program of public education about the scale, risks, and benefits of unconventional oil and gas development in Western Newfoundland;
- review and update public policy and regional development plans that describe the role, if any, of unconventional oil and gas development in the province;
- decide whether Government will make the investment required to better understand and mitigate key risks;
- safeguard Gros Morne National Park from development, and initiate the process to establish a buffer zone;

- undertake the basic scientific studies required to understand the potential impacts and geological-based risks of development, particularly risks related to health, environment, and seismicity;
- complete Health Impact Assessments for potential development regions;
- require that all engineering and geoscience work be undertaken by licenced professionals and companies with permits to practice in Newfoundland and Labrador;
- study potential development sites from a land-use perspective and with consideration to short-term and long-term coastal change;
- participate in national and international research programs related to well integrity; and
- establish an appropriate regulatory framework for unconventional oil and gas development.

If the results of implementing the red-stage recommendations lead to a decision that Government will give further consideration to permitting unconventional oil and gas development, the **'yellow-stage'** recommendations should be implemented. These recommendations include:

- model realistic full-scale development scenarios, including a plan for use of excess associated gas and a requirement for substantial local benefits, to better understand the costs and benefits of development;
- collect the baseline environmental, public health, and ecological data and model the effects of development;
- carry out further scientific studies related to understanding how the Green Point shale will respond to hydraulic fracturing operations, including an assessment of the prospect of using deep disposal wells for wastewater;
- review and update the environmental impact assessment process;
- complete an independent assessment of the associated environmental and public health risks;
- develop ongoing monitoring programs for collecting relevant environmental and public health data, for interpreting the data, and for publicly reporting on impacts;
- assess the potential impacts on civil infrastructure and services;
- develop an adaptive risk management framework, including an approach for monitoring and managing seismicity risks;
- undertake a review of the existing healthcare, fire and emergency services, and social services systems to identify the necessary improvements;
- implement additional elements of the regulatory framework, including mechanisms for meaningful public participation, participation by population and public health experts, and processes for review and continuous improvement of regulations;
- require proponents to implement community engagement plans that demonstrate public confidence has been attained and is maintained throughout a project;
- secure an equity position in future developments; and
- develop a well integrity monitoring program and require an appropriate security deposit from proponents.

These yellow-stage recommendations relate primarily to more site-specific studies or assessments needed in advance of industrial activity. During the yellow stage, the "pause" in accepting applications involving hydraulic fracturing could be removed so that some preparatory work could proceed (e.g., planning for exploration by proponents, and reviewing proposals from proponents by government and the regulator). Proponents, however, would need to understand that some of the yellow-stage recommendations include decision gates that could result in a decision by Government not to proceed further. For example, a more comprehensive cost-benefit study by the province, an independent assessment of risk, or new scientific knowledge, could lead to a decision that there is no basis to proceed with development.

The **'green-stage'** recommendations reflect the actions that the Panel believes need to be taken if, as a result of implementing the red-stage and yellow-stage recommendations, a decision is made by Government to permit unconventional oil and gas development in Western Newfoundland. There are numerous green-stage recommendations, primarily related to operational processes and practices, that the Panel feels will be straightforward to implement, assuming public confidence and support from the various community, industry, and

Government stakeholders has been achieved. These recommendations must be implemented before industrial activities commence and remain in place throughout a project. These recommendations include:

- require best practices to be followed by industry, including minimizing GHG emissions and installing groundwater monitoring wells;
- provide appropriate resources for heath care, social services, fire and emergency services, and community support;
- implement regular testing and reporting on population heath, air quality, water resources, and ecological species populations and health in areas where there is development;
- disclose the composition of all hydraulic fracturing fluids in a database that is in the public domain;
- plan development to minimize impacts on local residents;
- use best practices for site development, management, and decommissioning;
- minimize development impacts on lands, including footprints of well pads;
- minimize the risks to aquatic species;
- develop an abandoned well program;
- implement plans for waste and wastewater management, including seismic risk management if deep disposal wells are to be utilized;
- ensure health professionals have immediate access to accurate information about the composition of fluids used or produced at each development site; and
- ensure transparency in the management of risks, and engage independent experts in the oversight of the regulatory process, including the monitoring and evaluation requirements.

Implementing these staged recommendations constitutes a cautious way forward without pre-judging the impact and potential of unconventional oil and gas development in Western Newfoundland. Some of the recommendations give rise to decision points, where further evidence will inform Government decisions about whether to permit development or about any conditions or restrictions on specific activities that may be imposed. Some of the proposed recommendations can be pursued simultaneously, while others are interdependent. Recommendations related to public policy, planning, and science considerations must be acted upon first. The other recommendations can then be evaluated against up-to-date public policies that reflect economic development, energy planning, and climate change objectives, as well as an improved understanding of the fundamental geology of the resource.

The supplementary recommendations are presented in the context of *public policies*, *planning*, and *science*; *socio-economic*; *environmental*; *health*; *regulatory*; and other *scientific and technical* considerations. The recommendations are informed by the information gathered during the review process, including written submissions, public consultation sessions and other meetings; information provided by Government; direct sourcing of published documents by the Panel; and through work commissioned or undertaken by the Panel.

14.1 Public Policy, Planning, and Science Considerations

14.1.1 Provincial and Regional Planning

The Panel believes that unconventional oil and gas development in Western Newfoundland is primarily an economic development opportunity for the region. The benefits of this opportunity would be manifested through revenue-sharing from the export of oil, new employment in the region, and improved local infrastructure. Given the scale of impact on the day-to-day lives of people living in the region and the potential effects on other economic activities within the region, including tourism, agriculture, and fisheries, it is critical that unconventional oil and gas development be considered carefully within regional economic development plans. Current plans appear to be either out-of-date or are not being utilized, and all current plans predate consideration of unconventional oil and gas development in the region. The development of regional economic development plans should also include land-use planning that identifies areas suitable for industrial development and areas reserved for other activities.

Panel Recommendation (PR1): Update the Regional Economic Development Plans – Update or develop economic development plans for regions in Western Newfoundland that might be affected by unconventional oil and gas development and determine whether unconventional oil and gas development is consistent with the economic development priorities for specific regions. This should include an impact analysis on the relationship between unconventional oil and gas development and industries such as tourism, agriculture, and fisheries. Also, the process of developing economic development plans should include land-use planning. The planning process must be designed in such a way as to result in public confidence and support for the resulting plans.

The Panel agrees that energy developments in the province must be part of a provincial Energy Plan that maximizes the benefit of energy resources for the people of Newfoundland and Labrador. Realizing benefits from unconventional oil and gas development may require a significant investment by Government in further science to better understand the risks arising from exploitation of resources. This is certainly the case for the the Green Point shale resource. In addition, there needs to be an investment in civil infrastructure and services (e.g., roads, emergency services, health system) to be ready for full-scale unconventional oil and gas development. In the context of the Energy Plan (NL Energy Plan, 2007), Government investments in unconventional oil and gas development must be weighed against investments in other energy projects, such as further geoscience work off Labrador or in support of new offshore projects off the East Coast.

Since the Energy Plan predates an interest in unconventional oil and gas development in the province, it should be updated with consideration of the role, if any, for this potential opportunity. While commercial development of the Green Point shale has been primarily thought of as an oil development, there may be significant associated gas produced which needs to be considered in terms of how it will be utilized.

Looking into the future, the resources in Western Newfoundland may be a valuable source of oil for uses unrelated to the production of energy. That is to say, its long-term value may not be as a fossil fuel. It is not clear to the Panel how the current provincial policies support consideration of petroleum resources in a non-energy context.

Panel Recommendation (PR2): Update the Provincial Energy Plan – Review and update the provincial Energy Plan to consider and articulate the role, if any, that unconventional oil and gas development in Western Newfoundland will have among priorities related to energy development in the province. The review should also consider the future potential for non-energy applications of oil and gas resources.

Panel Recommendation (PR3): Develop a Plan to Use Excess Associated Gas – If there is a role for unconventional oil and gas development in Western Newfoundland, identify economic opportunities and a plan for utilization of excess associated gas from unconventional oil development.

14.1.2 Climate Change

Consideration of unconventional oil and gas development in Western Newfoundland must include an assessment of how such developments will likely impact the province's targets and aspirations with respect to greenhouse gas (GHG) emissions and climate change impact. This includes careful consideration of the province's Climate Change Action Plan (NL Climate, 2011) and any updates to this plan that are contemplated, particularly in view of provincial climate change objectives that follow from Canada's signing of the Paris Agreement (UNFCCC, 2015) at the 2015 Paris Climate Conference (COP21), and from Newfoundland and Labrador's participation in other climate change initiatives, such as signing the Climate Action Statement (CAS-CSA, 2015).

The Council of Canadian Academies Panel states:

> *"Shale gas is a fossil fuel, and its production and use lead to emissions of carbon dioxide and methane, both GHGs contributing to climate change. The environmental impact of shale gas with respect to anthropogenic climate change is not clear-cut"* (CCA, 2014).

The Council of Canadian Academies Panel goes on to note:

> *"How shale gas development affects climate change depends on its net contribution to global GHG emissions. Substituting natural gas for coal in electricity generation, for example, lowers carbon dioxide emissions per unit of energy produced, in part because of the greater efficiencies typically achieved in gas turbine power plants compared to coal-fired boiler power plants"* (CCA, 2014).

In order to fully assess the climate change impact, *"it is necessary to perform a full well-to-burner comparison of shale gas with other fuels that includes all sources of GHG emissions associated with the production, processing, transport, and consumption of each fuel"* (CCA, 2014).

Similar considerations to those noted by the Council of Canadian Academies Panel (CCA, 2014) for shale gas are relevant to considering the climate change impacts of development of an oil resource, such as the Green Point shale. Such an analysis, however, is beyond the scope of the work of the Panel and requires specific project details (e.g., how water, proppant, chemicals, and product will be transported; the type of completion technology that will be used; approaches to long-term monitoring and remediation of gas leakage).

The primary product from unconventional oil and gas development in Western Newfoundland is oil, with some associated gas. To date, attempts to demonstrate positive climate change effects from hydraulic fracturing have argued that produced natural gas replaces a fuel such as coal with a net reduction in GHG emissions (CCA, 2014). It is also important to note that oil from Western Newfoundland is not expected to be consumed within Newfoundland and Labrador, but would be exported to worldwide markets. This further complicates any well-to-burner analysis by *"a complex set of market factors and national and international policies"* (CCA, 2014).

As discussed in Section 6.2, overall GHG emissions from oil and gas production and use are primarily from burning of oil and gas as fuels (OGCI, 2015). The extent to which the oil will be used as a fossil fuel, compared to other non-fuel uses, needs to be considered in any "well-through-use" assessment of GHG emissions.

Within the province, the responsibility for the Climate Change Action Plan (NL Climate, 2011) rests with the Office of Climate Change and Energy Efficiency (OCCEE). In considering the GHG impacts, a more detailed development scenario needs to be prepared and analyzed by the OCCEE. Key considerations within the analysis include GHG impacts during development and production, including consideration of any venting or flaring of gas, and any fugitive gas emissions. As suggested in the Climate Change Action Plan, the analysis by the OCCEE needs to assess proposed development and production approaches to ensure *"that the most advanced machinery and equipment is utilized and that GHG emissions are minimized over the life of the facility"* (Janes, 2015).

As noted by the Council of Canadian Academies Panel:

> *"While published estimates of GHG emissions associated with shale gas production vary widely, they generally agree that the most important source of emissions is likely to occur during well completion"* (CCA, 2014).

Emissions can be significantly reduced by use of "green completion" techniques that capture a large percentage of the gas flow during the completion stage of development, and by minimizing the use of diesel-powered vehicles and equipment. Enhancing well integrity and prohibiting the flaring of gas minimize fugitive emissions. Should a decision be made to proceed with unconventional oil and gas development in Western Newfoundland, best practices with

respect to minimizing greenhouse gas (GHG) emissions should be required of industry.

Panel Recommendation (PR4): Evaluate the GHG Emissions Associated with Development – Engage the Office of Climate Change and Energy Efficiency to undertake a complete well-through-use assessment of the GHG emissions associated with a representative unconventional oil and gas development in Western Newfoundland. Careful consideration must be given to the results of this assessment and to the impact of development on the province's aspirations with respect to GHG emissions. It should also form the basis for specifying best practices of industry necessary to meet provincial GHG emissions objectives.

Panel Recommendation (PR5): Require Best Practices for Controlling GHG Emissions – Require industry to adopt best practices with respect to minimizing GHG emissions. This could include using "cleaner" fuel sources for vehicles and equipment, utilizing Reduced Emission Completions (RECs) or "green completion" techniques to capture produced gas during well completion, minimizing fugitive emissions associated with leaking wells, and prohibiting venting and flaring of gas associated with oil production or with the storage of chemicals or products.

14.1.3 Gros Morne National Park and UNESCO World Heritage

The Panel believes that there should be no hydraulic fracturing operations, as per the Panel's all-inclusive definition of hydraulic fracturing, within, adjacent to, or under Gros Morne National Park. Furthermore, the Panel is of the opinion that hydraulic fracturing operations should not be allowed to proceed in a manner that presents a credible threat to Gros Morne National Park as a UNESCO World Heritage Site or to the tourism industry that is developing in the Gros Morne area.

During the public consultation process, the concept of a "buffer zone" around Gros Morne National Park was raised repeatedly with the Panel. As described by UNESCO, *"any World Heritage buffer zone does not include outstanding universal value but provides additional protection for the outstanding universal value and integrity of the property"* (UNESCO, 2009).

While the designation of Gros Morne National Park as a UNESCO World Heritage Site predates the concept of buffer zones in the Operational Guidelines for the Implementation of the World Heritage Convention, the following paragraphs from the 2015 Operational Guidelines (UNESCO, 2015) are helpful in considering the notion of a buffer zone:

> *"103. Wherever necessary for the proper protection of the property, an adequate buffer zone should be provided.*
>
> *104. For the purposes of effective protection of the nominated property, a buffer zone is an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection. The area constituting the buffer zone should be determined in each case through appropriate mechanisms. Details on the size, characteristics and authorized uses of a buffer zone, as well as a map indicating the precise boundaries of the property and its buffer zone, should be provided in the nomination.*
>
> *105. A clear explanation of how the buffer zone protects the property should also be provided.*
>
> *106. Where no buffer zone is proposed, the nomination should include a statement as to why a buffer zone is not required.*

> *107. Although buffer zones are not part of the nominated property, any modifications to or creation of buffer zones subsequent to inscription of a property on the World Heritage List should be approved by the World Heritage Committee using the procedure for a minor boundary modification (see paragraph 164 and Annex 11). The creation of buffer zones subsequent to inscription is normally considered to be a minor boundary modification."*

The independent public opinion survey (MQO, 2015) commissioned by the Panel indicates that the vast majority of the respondents (92%) are in favour of a buffer zone around Gros Morne Park, with 60% of the respondents indicating that the buffer zone should be at least 25 km. The Panel agrees that a buffer zone should be established around Gros Morne National Park. It is, however, beyond the scope of work and expertise of this Panel to make a specific recommendation about the size of a buffer zone, although the Panel is in general agreement with submissions from Canadian Parks and Wilderness Society with respect to a general process to be followed to make such a determination (CPAWS, 2015a) (CPAWS, 2015b) (Burzynski, Marceau, & Cusson, 2015).

Panel Recommendation (PR6): Confirm a Ban on Hydraulic Fracturing Operations in Gros Morne National Park – Confirm a ban on hydraulic fracturing operations, as per the Panel's all-inclusive definition of hydraulic fracturing, in Gros Morne National Park. This includes not only hydraulic fracturing surface operations within the Park boundaries but also includes hydraulic fracturing under Gros Morne National Park.

Panel Recommendation (PR7): Establish a Buffer Zone around Gros Morne National Park – Establish an appropriate buffer zone around Gros Morne National Park so as to ensure that future industrial activity, including both onshore and offshore oil and gas development, does not negatively impact on the Park, its World Heritage Site designation, or the tourism industry that is developing around the Park. The establishment of a buffer zone should follow an open and transparent process that is informed by the UNESCO 2015 Operational Guidelines and involves relevant stakeholders, including the provincial and federal governments, local communities and businesses, local NGOs, and other relevant experts.

14.1.4 Understanding the Geology

If the public policy, regional planning, and climate change considerations indicate that unconventional oil and gas development in Western Newfoundland has a place within the province's future, it will be important to understand the geology of potential resources prior to permitting development. In particular, it is essential to understand the geology in order to assess the risks that are reflected in the concerns raised with the Panel about the use of hydraulic fracturing technology. The limitations in the current understanding of the Green Point shale are discussed extensively in the Green Point Report (Hinchey, et al., 2014). The need for further study of the geoscience in the region is also discussed in Appendix J (Burden, 2016), a review of the potential geological risks, and in Appendix K (Eaton & Krebes, 2016), a review of seismicity risks. A recommendation for additional geoscience study of the Green Point shale prior to the approval of any hydraulic fracturing operations also reflects sentiments expressed in many public submissions to the Panel (Sutherland, 2015) (WEC, 2015) (Oliver, 2015) (Corner Brook, 2015).

Such work will add to the scientific understanding of the Green Point shale and, as noted in the Green Point Report, also help to *"accurately depict or predict the extent, location, rock characteristics, or shape of Green Point shale layers below the surface"* (Hinchey, et al., 2014). As discussed in the Green Point Report, while large-scale, high resolution 3-D seismic surveys have become a routine approach to understanding sedimentary basins, *"true 3-D seismic data have yet to be acquired in Western Newfoundland"*. Most seismic data were collected in the 1980s and 1990s and are not considered to be up to modern standards.

A modern seismic program in the region is needed, coupled with stratigraphic well data analysis, which, as discussed

in the Green Point Report, *"would greatly improve the ability to predict where the Green Point shale occurs at depth, how the composition of the Humber Arm Allochthon varies internally, and how it was affected by regional deformation and faulting"* (Hinchey, et al., 2014).

The objective of a modern seismic program would be to gain a better understanding of the geology to be able to evaluate the risks of public concern that may be associated with any development or proposed approaches. These data are also *"crucial for designing – and predicting the effects of – an initial hydraulic fracturing program as well as any future production operations"* (Hinchey, et al., 2014).

Any public investment in a geoscience program should be consistent with previous provincial investments in geoscience work in support of developing a greater understanding of both offshore and onshore basins. In this context, the Panel believes that some of the gaps in knowledge about the Green Point shale can be addressed by the active participation of the provincial energy company, Nalcor Energy. Such participation may also help address public concerns about relying on the private sector to close current knowledge gaps.

Nalcor Energy describes its exploration strategy as follows:

> *"As the provincial energy company, Nalcor Energy undertakes strategic investments in new data acquisition and analysis at the front end of the exploration cycle to enhance knowledge of the prospectivity of offshore Newfoundland and Labrador's frontier basins, open new areas to industry exploration, and increase Newfoundland and Labrador's global competitiveness to attract exploration investment. Nalcor is not competitive with industry and therefore does not participate in bidding on land. Nalcor participates on behalf of the province in future projects through equity ownership in new successful developments"* (Nalcor, 2015).

For example, a recent regional pore pressure analysis study commissioned by Nalcor Energy had objectives that included de-risking of trap seal failures, developing a greater understanding of pressure regimes in the basin, developing a regionally consistent petrophysical model based on well data, and identifying key components for safe well planning. As discussed in a final report for that work, the aim of the study was *"to offer a definitive and comprehensive analysis of the region in order to provide enhanced confidence in the understanding of risk and pressure distribution to interested parties"* (Green, et al., 2013).

Nalcor Energy also recently partnered with C-CORE at Memorial University to develop *"the most comprehensive and accurate meteorological and oceanographic data set to characterize the metocean environment, covering topics such as winds, waves, currents, vessel icing, visibility (fog), pack ice, icebergs and ice islands, changes in conditions expected due to climatic change, and comparisons with other frontier regions"* (CCORE, 2015). The C-CORE report comments on the value of the study, along with the value of other studies commissioned by Nalcor Energy, in helping to increase scientific knowledge and identify risks associated with exploration offshore Newfoundland and Labrador. The report reads:

> *"In addition, Nalcor is making results from other selected studies (pore pressure analysis and rock physics) available to industry to increase scientific knowledge over a frontier exploration area. This metocean study is yet another source of information that interested parties may look to when defining the risks associated with an exploration program in the Newfoundland and Labrador offshore environment"* (CCORE, 2015) .

Appendix J, in reference to the potential development of the Green Point shale, recommends:

> *"Government efforts towards building greater industrial capacity in this part of Newfoundland and Labrador should include work with industry to understand these natural resources and to help define appropriate and safe recovery strategies. Logically, this should include (1) better measures of the*

size, shape, and quality of this potential resource, and (2) measures to confirm recovery is possible in rocks with complex structures and without compromising the quality of the surface and groundwater environments" (Burden, 2016).

As discussed by the Council of Canadian Academies Panel, *"deep disposal of wastewater poses two main hazards: risk of groundwater contamination and risks related to induced or triggered seismicity"* (CCA, 2014). While the report goes on to say that *"regions such as Quebec and the Maritimes generally do not have strata that would permit deep aqueous fluid disposal"*, it does not discuss the deep disposal of wastewater in relation to the geology of Western Newfoundland (CCA, 2014).
Burden (2016) describes the Port au Port #1 well as *"underpressured and unable to sustain flow"* which raises a question about *"whether an apparently naturally depleted and underpressured conventional hydrocarbon reservoir, 3500 m beneath the surface in Western Newfoundland, is able to accept expended fracking fluids"*.

As discussed in Appendix J (Burden, 2016) and Appendix H (Gagnon & Anderson, 2015), a scientific investigation needs to be conducted in order to understand the potential opportunity and risks of using Class II disposal wells for the management of wastewater from hydraulic fracturing operations.

Panel Recommendation (PR8): Undertake a Modern Geoscience Study of the Green Point Shale – Initiate a geoscience program, led by the Department of Natural Resources and Nalcor Energy, to collect the modern seismic and stratigraphic well data necessary to increase knowledge of and model the Green Point shale, or any other prospective resource, in the region of any potential development. This will lead to a better understanding of the geological-based risks of development, particularly those related to health and environment. The results of such a geoscience program should be available in the public domain.

Panel Recommendation (PR9): Assess the Prospect of Using Deep Disposal Wells for Wastewater – Initiate a geological assessment, led by the Department of Natural Resources and Nalcor Energy, of the potential opportunity and risks of using Class II disposal wells for the disposal of wastewater associated with hydraulic fracturing operations.

As discussed in Appendix M (Lahey, 2016) and recommended in Appendix K (Eaton & Krebes, 2016), a precondition of an unconventional oil and gas development in Western Newfoundland is an understanding of baseline seismicity in the region, as well as an understanding of how the structural environment will behave during hydraulic fracturing operations. One area for assessment is the integrity of the hydrostatic seal. As noted by Burden (2016), in reference to ancient geological processes, *"ancient structural damage to the strata may become an issue if, by fracking, the older faults and fractures are opened in an unacceptable manner and fluids are delivered to the surface"*. A better understanding of these important issues is an expected outcome of enhanced monitoring, modeling, and experimental studies in the region.

Panel Recommendation (PR10): Enhance Seismograph Network Coverage for Western Newfoundland – Enhance the seismograph network coverage in Western Newfoundland to improve monitoring capabilities for baseline seismicity. Given the current station distribution, at least one new station north and east of Anticosti Island would provide a significantly better geometry for event detection.

Panel Recommendation (PR11): Carry Out Baseline Seismicity Monitoring – Collect and analyze at least two years of baseline seismicity data from an enhanced seismograph network prior to development. The seismicity data, and its interpretation, should be available in the public domain.

Panel Recommendation (PR12): Complete a Geomechanical Investigation of the Green Point Shale – Conduct a geomechanical investigation that considers all available stress data and realistic structural models to address site-specific issues that pertain to the unique structural environment of the Green Point shale. The results of the geomechanical investigation should be available in the public domain.

In the event that unconventional oil and gas development in Western Newfoundland is feasible from a seismicity perspective, Burden (2016) suggests that *"at some point subsurface demonstration tests will have to be conducted to determine if commercial recovery is possible without compromising any of the surface and potable groundwater environment"*. This is in addition to the need for data from a modern seismic program noted in the Green Point Report (Hinchey, et al., 2014) and follows such a seismic program. Recognizing that industry may be the most appropriate partner for such demonstration tests, Nalcor Energy could become an equity partner, thereby being in a positon *"to ensure first-hand knowledge of how resources are managed, to share in that management, to foster closer government/ industry alignment of interests, and to provide an additional source of revenue"* (NL Energy Plan, 2007) .

Panel Recommendation (PR13): Implement a Pilot-Scale Stimulation Program – Based on the improved understanding developed through the recommended geoscience program, plan and execute a minimal-risk, pilot-scale well stimulation program, in cooperation with Nalcor Energy, to understand how the Green Point shale responds to stimulation and to further understand the associated risks. Such a stimulation pilot program should take place at a location significantly far from communities and utilizing best practices in risk assessment and management so as to reduce the environmental and health risks, and the associated public concern, to an acceptable level. The results of such a pilot program should be available in the public domain.

Panel Recommendation (PR14): Secure Equity in Industry-led Programs – Secure an equity position for Nalcor Energy in any industry-led exploration, development, and production programs. Such an equity position will serve as an influence mechanism to help ensure that any unconventional development best serves the interests of the people of the province.

14.2 Socio-Economic Considerations

14.2.1 Community Engagement

Government needs to ascertain whether sufficient public support exists to move forward with investing in the scientific studies that must precede development. Moreover, a decision to proceed with pre-development activities does not imply that a social licence currently exists or will exist in the future for a particular proponent or project to develop unconventional oil and gas resources in Western Newfoundland. As discussed in detail in Section 12, having a social licence requires a proponent to both earn and maintain public support and confidence throughout the lifetime of a project.

The Panel is of the opinion that those most affected by a development must clearly understand the scale, benefits, and risks as a precondition to Government gauging public support for unconventional oil and gas development in Western Newfoundland. Furthermore, the Panel believes that the affected people need to have meaningful participation in the decision-making processes that pertain to a decision whether to permit the development to proceed.

As noted by the Council of Canadian Academies Panel:

> *"Public engagement is necessary not only to inform local residents of development, but to receive their input on what values need to be protected, to reflect their concerns, and to earn their trust"* (CCA, 2014).

As discussed in Appendix M, best practice in community engagement requires that community engagement go *"beyond obligatory consultations and instead aims to achieve and sustain a deeply rooted social licence"* (Lahey, 2016). Despite the lack of clarity with respect to how the concept of a social licence may be operationalized, Lahey states:

> *"Engagement must also seek alignment with community values and identify and maximize the benefits to the community that development can bring"* (Lahey, 2016).

As discussed by Lahey (2016), regulations related to hydraulic fracturing operations *"can and should require proponents to have and implement a stakeholder or community engagement plan that is capable of achieving the larger goals of community engagement"*.

At present, the Panel does not believe that the necessary understanding exists about important issues that are key to the decision about whether to support development. There is an insufficient understanding of:

- local, regional, and provincial benefits;
- health risks and benefits;
- environmental risks and mitigation approaches;
- local and regional impacts on civil infrastructure and services, including transportation infrastructure, housing, health and community services, and fire and emergency services; and
- impacts on the day-to-day life of people living in the vicinity of potential operations or related activity during exploration, development, and production.

In the absence of an understanding of these issues by the public, the Panel feels that it would be premature for Government to attempt to gauge whether there is public support by those most affected by a potential development.

The lack of public understanding about unconventional oil and gas development is not unique to Newfoundland and Labrador. Research carried out by the Canadian Water Network reports that, within Canada and the United States, *"the general public has only limited knowledge of fracking"* (Quinn, et al., 2015). With respect to the purpose of an education program, Quinn et al. (2015) go on to say:

> *"While many members of the public remain ill-informed about shale gas development, it is often inaccurately assumed that a public misunderstanding or ignorance is a solvable problem, namely that providing more information will somehow move public opinion".*

It is the view of the Panel that public education must not become an effort to persuade people toward a particular position, for or against development. Rather, public education must advocate for the facts about unconventional oil and gas development set within the context of Western Newfoundland.

In the Panel's opinion, Government is responsible for ensuring that a process exists through which the public can become sufficiently knowledgeable on key issues related to unconventional oil and gas development in Western Newfoundland. This knowledge, as it relates to scale, benefits, and risks, will facilitate better-informed consultation and decision-making. There could be a role for Memorial University, in cooperation with other institutions and organizations, in terms of both helping to provide programs of public education and removing some of the existing knowledge gaps. An illustration of the role that Memorial University can fulfill is the Marcellus Center for Outreach and Research at Penn State University. The Marcellus Center provides science-based, educational programming on shale gas issues to *"state agencies, elected and appointed officials, communities, landowners, industry, environmental groups, and other stakeholders"* (Marcellus, 2010). Through its Marcellus Matters programme, the Marcellus Center also plays an important role in helping communities deal with changes resulting from development, increasing knowledge, and bringing together *"citizens to engage in civil dialogue around polarizing issues within their communities"* (Marcellus, 2010).

The Panel feels that in the case of unconventional oil and gas development in the Port au Port Bay area, such as that contemplated by the scenario discussed in Section 9, there needs to be ongoing public support for development. Moreover, the greatest weight should be given to the level of support from people living and working in the communities on the Port au Port Peninsula, around Stephenville, and along the West Coast between the Port au Port Peninsula and Fox Island River. A similar requirement for local support would also be the case for any potential developments in other areas of Western Newfoundland. Public support, however, does not mean agreement by every individual or interest group in these communities, but it should reflect ongoing support by a significant majority of the residents of the most affected communities.

The Panel is of the view that Government, as the elected representatives of the people, ultimately has the authority and responsibility, with meaningful and appropriate input from the people that it represents, to make decisions related to unconventional oil and gas development in Western Newfoundland. Furthermore, any process to gauge ongoing public support for a development should be clearly defined and set within appropriate regulatory and legal frameworks.

Panel Recommendation (PR15): Develop a Program of Public Education About the Benefits, Risks, and Scale of Development – Develop an ongoing program of public education with a focus on benefits, risks, and scale of unconventional oil and gas operations, with a particular focus on Western Newfoundland. This could involve Memorial University of Newfoundland, in partnership with other institutions and organizations, developing an independent centre for education and research similar to the Penn State Marcellus Center for Outreach and Research.

Panel Recommendation (PR16): Assess the Support for Public Investments Required to Understand and Mitigate Key Risks – With confidence that there is an appropriate level of public understanding of the issues associated with hydraulic fracturing operations in Western Newfoundland, develop a process to determine whether there is sufficient public support, particularly from the individuals living and working in the communities most directly affected by development, to proceed with the public investment to undertake the work necessary to understand and mitigate outstanding key risks.

Panel Recommendation (PR17): Require Proponents to Demonstrate Effective Community Engagement and Public Confidence – Require any potential industry proponent to develop and implement a plan for meaningful and ongoing community engagement throughout the life of a project. The plan must include processes, metrics, and a reporting framework to demonstrate that public confidence has been achieved prior to undertaking development and that it is maintained throughout the life of a project. Such a plan and the associated reporting would be subject to approval and review within the framework of regulation of the industry.

While its context is very different from unconventional oil and gas development, the approach to stakeholder engagement in the Giant Mine Remediation Project (GMRP) may be helpful in identifying effective ways of facilitating community engagement (GMRP, 2015). The GMRP deals with the clean-up of a mine in the Northwest Territories that closed in 2004. In addition to engaging First Nations, municipalities, and other organizations, the project also includes a community alliance which *"assists the public by sharing information about the project and relaying public concerns and issues about the remediation of the Giant Mine"* (GMRP, 2015).

The GMRP also includes an independent peer review panel that provides ongoing evaluation of the remediation plan and ensures *"the design and implementation of the project follows industry best practices, provides good value to the Crown, and is technically robust"* (GMRP, 2015). Finally, specialist advisors are retained by the federal government to provide independent advice with respect to the major areas of technical risk. If adopted early, an approach such as that taken in the GMRP may be helpful in building public confidence in decisions about whether to allow

unconventional oil and gas development in Western Newfoundland. This could be particularly helpful in ensuring that evidence-based decisions are made at the key decision points. There are also other discussions of best practices with respect to community engagement in natural resource development projects that are useful to consider (NRCAN, 2015) (OSEA, 2010) (Penn, 2016).

> **Panel Recommendation (PR18): Review and Adopt Best Practices in Community Engagement –** Review and adopt best practices in community engagement, supported by independent assessment and review to ensure that evidence-based decisions are made at key future decision points associated with unconventional oil and gas development in Western Newfoundland.

14.2.2 Risk Assessment and Management

In many submissions and presentations to the Panel, the Precautionary Approach is suggested as the approach that the Panel should recommend to Government. In some cases, such as in a submission by the Gros Morne Coastal Alliance (GM Coastal, 2015), individuals or groups making a submission with such a recommendation, when asked by the Panel to clarify their position, confirmed that they are recommending an outright, perpetual ban on hydraulic fracturing operations as they are opposed to unconventional and, in some cases, conventional oil and gas development in the province. In other cases, the call for a ban, or adoption of a Precautionary Approach, reflects concerns about specific aspects of hydraulic fracturing operations and the need for a continued "pause" until it is clear that the risks, primarily to public health and environment, are understood and can be managed effectively.

There are many different activities, with varying levels of risk, that constitute hydraulic fracturing operations. Hence, there are many activities that need to be managed from a risk perspective. Some of the risks arising from these activities are well understood and lend themselves to effective management using the As Low as Reasonably Practicable (ALARP) principle, while other risks, which are less well understood, may be appropriately managed in the context of Adaptive Management or the Precautionary Approach.

The Panel is in general agreement with the recommendations of the Council of Canadian Academies Panel that:

> *"Given the current knowledge gaps, a science-based, adaptive, and outcomes-based regulatory approach is more likely to be effective than a prescriptive approach, and is more likely to result in an increase in public trust"* (CCA, 2014).

Also, the Panel agrees with the Council of Canadian Academies Panel that *"there is opportunity to put in place the management measures required, supported by appropriate research, to reduce or avoid some of the negative environmental effects of this development"* and that *"we need to proceed slowly, take measurements, understand the science, be guided both by facts and by public acceptability"* (CCA, 2014).

The Panel is also in agreement with the conclusion of the Nova Scotia Independent Review Panel that:

> *"Having citizens and communities involved in the risk assessment and decision-making processes regarding unconventional gas and oil development would be an important first step co-generating the knowledge that may help to unlock and mitigate potential problems before they occur, while increasing trust amongst stakeholders"* (NSIRPHF, 2014).

As discussed by the Council of Canadian Academies Panel, *"organizations will need to be able to adapt to new knowledge about shale gas as it is acquired, and implement new mitigation measures or modify existing ones during the life of development projects"*, and there is a need for *"advanced planning to put a systematic process in place for continuous improvement of environmental management practices through learning about their outcomes (an adaptive management approach)"* (CCA, 2014).

Should the province, following consideration of unconventional oil and gas development from the perspectives of the provincial Energy Plan, regional economic development plans, and the Climate Change Action Plan, and having received public support to undertake pre-development work, determine that it wishes to proceed further with considering unconventional oil and gas development in Western Newfoundland, the Panel believes that an independent study of the risks for a more detailed development scenario should be undertaken. This should include meaningful stakeholder engagement and have the objectives of identifying the primary risks in the context of development of the Green Point shale and recommending further research and appropriate risk management measures. The scenario included in Section 9 of this report could form the basis for development of a more detailed scenario.

Based on the work of this Panel and the risks highlighted in this report, the Panel believes that Adaptive Management, supplemented with elements of the Precautionary Approach where warranted, offers the most appropriate way forward with respect to risk management. Since Adaptive Management is an evolving process of risk management, it is critical to include meaningful stakeholder engagement as part of the risk management framework. This is particularly important since risk perception directly influences public confidence.

> **Panel Recommendation (PR19): Assess the Environmental and Public Health Risks –** Supported by baseline environmental and health data, initiate an independent assessment, with meaningful stakeholder engagement, of environmental and public health risks associated with a representative scenario for industrial-scale hydraulic fracturing operations in Western Newfoundland. This assessment, which should be available in the public domain, should identify the primary risks, and identify further research required.

> **Panel Recommendation (PR20): Implement an Adaptive Management Framework to Manage Risks –** Identify risk management measures appropriate for each identified risk. The work would put in place the elements of an Adaptive Management framework, supplemented as appropriate with elements of the Precautionary Approach and including meaningful stakeholder engagement, that could be utilized in the assessment and management of risks associated with any future full-scale unconventional oil and gas development in Western Newfoundland. The resulting risk management framework should be available in the public domain.

14.2.3 Economics of Full-Scale Operations

Western Newfoundland in general, and the Stephenville-Port au Port local area in particular, have demographic, income, and labour market challenges that could benefit from new economic opportunities. For this reason, it is important to give full and fair consideration to the opportunities to generate local employment and income from new industries in Western Newfoundland, including unconventional oil and gas development opportunities.

As discussed in Section 9, analysis of the base case project (i.e., 150 million barrels at $85 U.S per barrel) indicates that, while not transformative for the province from either fiscal or employment perspectives, there could be significant local economic and employment impacts from a development. On an annual basis, unconventional oil and gas development around Port au Port Bay could add approximately 1,100 full-time equivalent jobs throughout the province during the six years of well construction, including approximately 300 local full-time equivalent jobs in the Stephenville-Port au Port local area. During the 26 years of production, depending on the option selected for handling of wastewater, it is estimated that there would be, on average, an additional 60-75 annual full-time equivalent jobs in the province, with annual employment in the Stephenville-Port au Port local area estimated to be between 30-40 full-time equivalent jobs. Additionally, road construction and upgrading required prior to unconventional oil and gas development could supplement local employment by another 200 full-time equivalent jobs in the Stephenville-Port au Port local area during the three years of road construction and upgrading. This employment estimate does not include potential employment from operation of the electricity generation and distribution system nor from the operation of

the marine terminal. The scale of both of these activities, and hence the level of employment, depends on a number of factors, including plans for the utilization of the associated gas and the possibility of on-island treatment of wastewater, which may be feasible if an industry, rather than a single project, is developed.

The Panel heard concerns about the impact on other established or developing industries in Western Newfoundland, particularly tourism and the fishery. It is important that a more detailed economic analysis include a thorough assessment of the impact on those industries. This more detailed analysis should also consider the costs of implementing the Panel's recommendations since some of the actions (e.g., ongoing environmental and health status monitoring and interpretation) will require both capital and operating expenditures.

Finally, for the illustrative project, the annual average revenue to the provincial government from the corporate income tax, royalties, and profit sharing from such a project could be $84-$136 million per year over 26 years depending the option selected for disposal of wastewater. The corresponding annual equivalents of local area revenues are estimated to be $273,000-$973,000 depending on the revenue-sharing model adopted. Gross Domestic Product (GDP) impact in the province from oil production is estimated to be $350-$500 million annually for the life of the project (NLHFRP, 2016d).

While the estimated activity from hydraulic fracturing will not transform the province, it could help boost economic activity within the local area in the near term. While it is important not to raise expectations about local economic benefits beyond what is reasonable, it is also important not to minimize the potential that unconventional oil and gas development might have for the local area under the right conditions. These right conditions include effective regulation of industry and management of risks.

> **Panel Recommendation (PR21): Update the Development Scenario as a Basis for a More Complete Cost-Benefit Analysis –** With greater clarity with respect to geological, health, and environmental risks and risk management, review and revise the scenario considered by the Panel in order to carry out a more detailed cost-benefit analysis, with particular consideration to the costs and benefits to the province and the people of Western Newfoundland. This analysis should be based on a more detailed scenario for unconventional oil and gas development that offers a fair rate of return to project proponents. The analysis should include a thorough assessment of the impact on other established and developing industries, with a particular focus on employment impacts, and should also include a detailed assessment of the impacts on public and social services. The costs associated with environmental and public health monitoring, including interpretation of data, must also be included in the analysis. This analysis should be made available in the public domain.

14.2.4 Civil Infrastructure and Services Impacts

Beyond the economic and fiscal considerations, other issues arising from such a development and that affect the day-to-day lives of people in the area of development need to be considered (BCOGC, 2015). This is particularly important when the scale of activity increases beyond the initial exploration work. As discussed in Section 9.3.3.5, a significant increase in heavy vehicle traffic would likely occur during development and production.

The higher level of truck traffic during construction may be reduced by the use of barges and pipelines to bring the components of the hydraulic fracturing fluid closer to each well pad, perhaps to local storage locations that could supply several well pads. While the use of local storage locations might not reduce the overall number of truck movements during construction, it could allow construction traffic to be mostly local to a well pad, reducing the overall distance travelled by the trucks and decreasing construction traffic on public roadways. Any scenarios that consider the use of barges must take into account that there is significant ice cover of the near-shore waters around the Port au Port Peninsula between January and March (Amec, 2014).

There are many ways to mitigate traffic impact on local communities. A few of the options that have been implemented or considered elsewhere include:

- construct by-pass roads for vehicles that would be involved in the development;
- prohibit all but emergency truck traffic during school bus or other commuter hours;
- convoy trucks in groups of 10-12 with traffic control to reduce disruptions;
- favour small, buried flowlines for fluid transport instead of tanker trucks;
- design and stock local stockpiles, as appropriate, to avoid sudden surges in traffic; and
- create stockpiles through barging to shorten trucking distances.

It is estimated that approximately 100 km of main roads around Port au Port Bay would need to be upgraded to a level where heavy truck traffic could share the roads with public traffic. Alternatively, by-pass roads could be constructed to separate public traffic from traffic involved in construction and production. While traffic impacts may be minimized, any sort of large-scale industrial development on the Port au Port Peninsula will involve an increase in heavy vehicle traffic experienced by people living in the communities in the region.

As discussed in Appendix Q (Rodgers, 2015) and illustrated in Section 9, most of the scenarios considered by the Panel can sustain a requirement to make a $100 million investment into new or upgraded roads in order to reduce the externalities imposed by congestion on local roads. Moreover, these corrective expenditures will also yield economic impacts for the region that should be taken into account in any assessment. It is the case that any development should be able to ensure that external costs imposed upon the local impact area are minimized.

Shoal Point Energy proposes using seawater instead of freshwater as the make-up water for the hydraulic fracturing fluid (Shoal, 2015b). Schlumberger promotes a fracturing fluid that uses seawater as make-up water (Schlumberger, 2016b). The Panel's analysis did not consider the technical feasibility of using seawater rather than freshwater, the cost of the fracturing fluid, or the cost of the fluid transportation alternatives (e.g., cost to build a pipeline to transport make-up water to the well pad sites). Furthermore, if the possibility of utilizing seawater as make-up water is to be pursued, it will be essential to understand the effects with respect to corrosion of equipment and the interactions between saltwater and other chemicals used or produced during, or as a result of, hydraulic fracturing.

As noted in a submission to the Panel by the Petroleum Services Association of Canada (PSAC, 2016a), and discussed in the literature (Boschee, 2012) (CH2MHILL, 2015) (CAPP, 2012b), re-use of flowback and produced water could be favourable in terms of project economics and transportation impact considerations. This is particularly true if the supply of make-up water is limited.

While other physical infrastructure, such as schools and hospitals, could be affected by a project of the scale discussed in Section 9, the size of the local employment impacts and the relatively short duration of the peak impacts during construction are not expected to dramatically overextend these facilities. Hence, additional physical infrastructure needs are not expected to be significant for the illustrative project considered by the Panel. This situation may be different, however, if an unconventional oil and gas industry, rather than a single project, is established in Western Newfoundland. The Panel is in agreement with the submission by the Qalipu Mi'Kmaq First Nation Band that there needs to be:

> *"A study or infrastructure analysis completed to assess and address the issues with regards to roadways and other services in the area that would require attention and a potential increase in demand and/or use. For any outstanding issues to be addressed before the project start date and improvements made to accommodate said increases"* (Qalipu, 2016).

Panel Recommendation (PR22): Assess Impacts on Civil Infrastructure and Services – Undertake a comprehensive civil infrastructure and services assessment in view of a detailed full-scale development scenario. This assessment should account for the impacts associated with development and identify the required physical infrastructure and service upgrades. The required upgrades should be carried out in advance of stresses on the existing infrastructure and services. This should include a plan for maintaining the physical infrastructure and services during the project lifecycle and consideration of implications of maintaining the physical infrastructure and services, as required, beyond the lifetime of the activity.

Unconventional oil and gas development in Western Newfoundland may require enhanced fire and emergency services. As described in a submission to the Panel by Fire and Emergency Services – Newfoundland and Labrador (FES-NL), local governments in Newfoundland and Labrador are required under the Emergency Service Act (NLESA, 2008) to develop emergency management plans (McCormack, 2016). In developing the plans, the local government *"undertakes hazard identification and risk assessment for the local environment including geophysical attributes and commercial/industrial activities, and considers historical events"* (McCormack, 2016). The Act provides for multiple local governments to join together to develop a regional emergency management plan (NLESA, 2008). In 2007, Stephenville and the associated Bay St. George communities prepared a regional emergency management plan (S-BSG, 2007). While the plan identifies oil spills as a potential emergency that may affect the region, it is silent with respect to identifying potential major effects, the actions required following an incident, and the agencies responsible for carrying out the actions. The development of the regional emergency management plan predates consideration of an unconventional oil and gas industry in Western Newfoundland. The Panel is in agreement with FES-NL that:

> *"Should hydraulic fracturing operations proceed on the Port au Port Peninsula, then the regional emergency management plan would be reviewed to ensure that the existing document provides sufficient guidance should an adverse event occur related to hydraulic fracturing operations or if changes and enhancements are required to the emergency management plan to meet the new commercial/industrial activity within the region"* (McCormack, 2016).

Given that the current regional emergency management plan is silent with respect to oil spills, the Panel believes that the current plan will be inadequate to deal with potential incidents that may arise in relation to a full-scale oil and gas industry in the region. To respond effectively to potential incidents, including having the appropriate equipment and human resources, the Panel believes that the emergency response requirements should be identified early and included in any further cost-benefit analysis as recommended by PR21 in Section 14.2.3.

Panel Recommendation (PR23): Assess the Fire and Emergency Services Capacity – Undertake a comprehensive assessment of the fire and emergency services associated with a full-scale unconventional oil and gas industry in Western Newfoundland. This should include an assessment of the existing regional emergency management plan.

Panel Recommendation (PR24): Enhance the Fire and Emergency Services Capacity – Ensure that the necessary capacity to provide the required fire and emergency services is developed in advance of unconventional oil and gas development.

Finally, risks to local populations can be mitigated to some degree by ensuring that well pads, processing facilities, and access roads are located in areas that impose lowest possible costs and inconvenience for local populations.

Panel Recommendation (PR25): Mitigate Risks to Local Populations by Careful Planning for Development – Select sites for well pads, central facilities, and access roads with consideration to proximity to homes and populated areas, including sight lines from roadways and other public sites in the vicinity of well pads.

14.3 Environmental Considerations

There are environmental impacts from unconventional oil and gas development, as there are with other forms of large-scale industrial activity, such as conventional oil and gas development, forestry, mining, and agriculture. These impacts are on the air, water, and land in the vicinity of industrial development, as well as more broadly through the effect of greenhouse gas (GHG) emissions on climate change.

Dr. Graham Gagnon, a member of the Panel and NSERC Industrial Research Chair in Water Quality and Treatment at Dalhousie University, prepared a report dealing with water supply, quality, and treatment issues relevant to unconventional oil and gas development in Western Newfoundland. This report is included as Appendix H (Gagnon & Anderson, 2015).

The Panel commissioned Dr. Tahir Husain, a Professor of Civil Engineering at Memorial University and an expert in environmental engineering, to provide a perspective on potential environmental impacts of unconventional oil and gas development in Western Newfoundland. Appendix I includes a report on this work (Husain, et al., 2016).

Appendix H and Appendix I, along with the report of the Council of Canadian Academies Panel (CCA, 2014) and research reports from the Canadian Water Network (CWN, 2015a), provide detailed reviews of the environmental considerations that are important if unconventional oil and gas development is to be pursued in Western Newfoundland. The Council of Canadian Academies Panel states:

> *"Two issues of particular concern to panel members are water resources, especially groundwater, and GHG emissions. Both relate to well integrity. Many of the operational procedures used in shale gas extraction are similar to those used in conventional oil and gas extraction. Thus industry experience is relevant to understanding these issues"* (CCA, 2014).

If unconventional oil and gas development is to take place in Western Newfoundland, the following recommendations should be considered in order to minimize negative impacts on the environment. These recommendations are broadly consistent with the recommendation of the Qalipu Mi'Kmaq First Nation Band that there be:

> *"Mandatory collection of baseline data regarding the chemical composition of well water and adjacent groundwater and artesian wells, along with other environmental indicators (both marine and terrestrial), to do a before and after control impact study to understand the effect of the potential proposed hydraulic fracturing in the area"* (Qalipu, 2016).

Specific recommendations of the Panel related to climate change impacts are presented in Section 14.1.2 of this report.

14.3.1 Air Quality Impacts

As discussed in Appendix I, all phases of unconventional oil and gas development produce air emissions from sources such as combustion engines and other on-site and transportation equipment; flowback and produced water; and proppant, dust, chemicals, spills, and other gas releases (Husain, et al., 2016). While these air emissions are similar to those from conventional oil and gas operations, emissions from unconventional oil and gas operations are higher per unit of oil and gas produced since more energy is required due to *"longer drilling times, more trucks being used, more powerful pumps, and bigger holding ponds"* (CCA, 2014).

As noted in Appendix I (Husain, et al., 2016):

"In general, the air emissions involved in fracturing operations can be categorized as

- *On-site criteria pollutants and their precursors: carbon monoxide (CO), lead, nitrogen oxides (NO_x), O_3, PM [particulate matter], sulfur dioxide (SO_2), and VOCs [volatile organic compounds];*
- *Air toxics and other HAPs [hazardous air pollutants], including fugitive emissions from mixing chemicals, spills, and flowback fluids (which can also include VOCs); and*
- *GHG emissions such as carbon dioxide (CO_2) and CH_4 (methane)".*

There are particulate emissions from the combustion engines of trucks and machinery used in hydraulic fracturing operations. Particulate matter that is smaller than 10 micrometres in diameter *"poses a health concern because it can pass through the throat and nose and accumulate in the respiratory system"* (Husain, et al., 2016).

The immediate and cumulative impact of industrial activity on air quality must be evaluated against baseline data for the region potentially impacted. Currently there is limited direct air quality data for the Port au Port region.

As discussed in Appendix I, a number of best practices should be implemented to ensure that air quality is protected. These include effective monitoring of air quality; establishing baselines for air quality; minimizing greenhouse gas emissions by using green completion technologies; tracking and reporting of emissions throughout operations; utilizing air dispersion modeling to understand local air quality impacts and to *"assist in the design of effective strategies to reduce those air pollutants harmful to human health"*; managing fugitive emissions; and prohibiting venting of associated gas (Husain, et al., 2016).

Panel Recommendation (PR26): Complete Baseline Testing of Air Quality – Undertake baseline testing of air quality in the vicinity of anticipated hydraulic fracturing operations. This should include establishing a database of baseline data that would be in the public domain.

Panel Recommendation (PR27): Model Potential Air Quality Effects – Utilize best available air dispersion modeling techniques to understand and predict the movement of air pollutants in the atmosphere most affected by hydraulic fracturing in Western Newfoundland. Utilize this knowledge in the design of effective strategies to monitor air quality and to mitigate risks of air pollution.

Panel Recommendation (PR28): Require Regular Testing and Reporting of Air Quality – Implement ongoing regular testing and public reporting of air quality data, including interpretation of the results, in areas associated with hydraulic fracturing operations. Maintain these data in an emissions inventory that would be in the public domain.

As recommended in Section 14.1.2, **Panel Recommendation (PR5): Require Best Practices for Controlling GHG Emissions** also helps minimize the negative impact on air quality.

14.3.2 Water Impacts

The Canadian Water Network (CWN) brings together researchers, industry, government and NGOs to improve the state of water management in Canada. Within its programs, the CWN *"established a national program on water and hydraulic fracturing to identify key questions and support the generation and use of knowledge to inform decisions"* (CWN, 2015a). Among the topics considered by the CWN are water governance, water safety, management approaches, wastewater management, subsurface impacts, and landscape impacts.

With respect to potential water impacts in Western Newfoundland, the Panel reviewed publicly available water quality data and reports to gain a further understanding of the baseline water quality in the Port au Port area. Based

on this review, which is included in Appendix H of this report, the Panel believes the overall quality of drinking water in the Port au Port area may already be of low quality (Gagnon & Anderson, 2015). Water quality data, however, is extremely limited and there is a need to understand present day conditions to ensure that an industrial process, such as unconventional oil and gas development, does not result in further deterioration of the quality of the groundwater system. The limitations of the currently available surface and groundwater data for Western Newfoundland are also highlighted by Burden (2016):

> *"Provincial water records contain few or no baseline measures for methane, other hydrocarbons, stable isotopes, and other complex chemicals in groundwater deposits. Nor were there any reports discovered for the stratigraphy of water and for explaining the regional distribution of water deposit chemistry".*

Burden (2016) goes on to say that the *"outcrop geology for the region leaves no doubt that there are many places where hydrocarbons are naturally leaking into the surface and groundwater environment"*. Chemical analysis of water from some wells indicates that surface and groundwater are likely affected by water from deeper water sources. Burden (2016) concludes that *"our near total lack of appreciation of the chemistry, distribution and movement of water in bedrock is an important unresolved risk"*.

Based on the review of local water resources in the Port au Port area, the Panel believes that the quantity of freshwater in the immediate Port au Port area is limited relative to the quantities required for unconventional oil and gas operations. Again, the data available for this review were limited. It would be essential to undertake a complete assessment of freshwater availability and existing use prior to making a decision to use local water sources for unconventional oil and gas development. This should include modeling of water supply and demand (CWRS, 2015). As well, such an assessment would include an evaluation of the aquatic species that are supported by the water sources in the area.

Panel Recommendation (PR29): Complete Baseline Testing and Modelling of Water Resources – Undertake baseline testing and modeling of water resources, including groundwater and surface water, in the vicinity of anticipated hydraulic fracturing operations. This would include establishing a database of baseline data in the public domain.

Panel Recommendation (PR30): Require Regular Testing and Reporting on Water Resources – Implement ongoing regular testing and public reporting of groundwater and surface water resources in areas associated with hydraulic fracturing operations.

A wastewater management plan will be required (Gagnon & Anderson, 2015). While practices in other jurisdictions are evolving, there are no standards with respect to *"design, monitoring, and management standards/requirements for hydraulic fracturing waste storage facilities (e.g. tanks, ponds, etc.)"* (CWRS, 2015). As discussed in Appendix H, the wastewater management plan would include wastewater discharge regulations, required treatment technologies that minimize the risks to aquatic species from cumulative effects, and appropriate monitoring requirements.

Panel Recommendation (PR31): Implement a Wastewater Management Plan – Implement a wastewater management plan that requires samples of hydraulic fracturing fluids, flowback, and produced water to be analyzed regularly by the regulator to ensure compliance with the approved plan. The regulator should include the analysis results in the disclosure report for each well.

Panel Recommendation (PR32): Minimize the Risks to Aquatic Species – Identify and implement mitigation strategies and wastewater handling and treatment approaches that minimize risks associated with immediate and cumulative effects to aquatic species in any "at risk" bodies of water.

14.3.3 Land Impacts

Unconventional oil and gas development involves drilling many wells from a number of well pads that are geographically distributed. For example, the scenario discussed in Section 9 for the Port au Port region includes 480 wells from 30-40 onshore well pads distributed around Port au Port Bay. While there would be land impacts at each of the well pads, there would also be impacts from transportation and other central support infrastructure (e.g., access roads, central processing facilities and main gathering lines, water pipelines, main gas line, storage and loading facilities, electricity generation facilities, electricity distribution lines). These impacts will mostly be felt in the Port au Port region and in Stephenville, which might serve as a port and service centre for an unconventional oil and gas industry in the region.

As discussed by the Council of Canadian Academies Panel:

> *"Shale gas development involves the same mix of construction and industrial activities as conventional gas development but at a higher intensity because: (i) the resource covers large geographical areas; (ii) production declines quickly requiring a large number of wells to be drilled to keep production stable; and (iii) individual shale gas wells need to be spaced more tightly together to drain the reservoir efficiently due to the rock's low permeability. In terms of land impacts, however, it is the pad size and its spacing (as opposed to well spacing) that is most significant. Having multiple wells on a single pad is environmentally preferable"* (CCA, 2014).

Furthermore, consideration of land impacts cannot *"focus on a single well or well pad, but must also consider regional and cumulative effects"*, and *"land impacts may include deforestation, the destruction and fragmentation of wildlife habitat, and adverse effects on existing land use such as agriculture and tourism"* (CCA, 2014). The impacts on land currently used for recreational or hunting purposes needs to be evaluated. Land use should be carefully considered within the context of developing regional economic development plans as recommended in Section 14.1.1.

While the use of horizontal wells drilled from multi-well pads reduces the impacts compared to vertical wells, unconventional oil and gas developments can have *"substantial impacts on communities and ecosystems"* (CCA, 2014). As discussed in Appendix I, local soil contamination is possible from surface spills from equipment used during well stimulation and from improper storage of hydraulic fracturing fluids or produced water (Husain, et al., 2016). Ecologically sensitive areas need to be protected from potential damage.

Panel Recommendation (PR33): Complete Baseline Testing of Ecological Species Populations and Health – Undertake baseline testing of ecological species populations and their health, including interpretation of the results, in the vicinity of anticipated hydraulic fracturing operations. This should include establishing a database of baseline data in the public domain.

Panel Recommendation (PR34): Require Regular Testing and Reporting of Ecological Species Populations and Health – Implement ongoing regular testing and public reporting of ecological species populations and their health, including interpretation of the results, in areas associated with hydraulic fracturing operations.

Panel Recommendation (PR35): Require Best Practices for Site Development, Management, and Decommissioning – Employ standards, certification processes, and best practices for the development, management, and decommissioning of all sites and infrastructure associated with unconventional oil and gas development.

Panel Recommendation (PR36): Minimize the Development Impacts on Lands – Select sites and designs for well pads, central facilities, and access roads to minimize the short-term and long-term impact on land, including wildlife habitat and other ecologically sensitive areas.

Panel Recommendation (PR37): Minimize Site Footprints Following the Construction of Wells – Optimize the planning of drilling, completion, and well stimulation to "shrink" development footprints on land back to some appropriate minimum size during production.

14.3.4 Coastal Change and Erosion

Consideration of unconventional oil and gas development around Port au Port Bay needs to include a careful assessment of the short-term and long-term prospect of coastal change and erosion in the vicinity of unconventional oil and gas infrastructure, particularly any infrastructure that will be permanently installed. This would include well pads and wells. Given the prospect of locating permanent infrastructure in close proximity to the coastline, including on Long Point and Shoal Point, it is particularly important to understand and take into account possible short-term and long-term coastal change and erosion in the Port au Port Bay area.

Knowing that the rates of coastal erosion at some locations within a prospective development area are higher than the provincial average, it is important to establish appropriate setback limits for any operations or land disturbances resulting from unconventional oil and gas operations (NLGS, 2016). As noted by the Geological Survey :

> *"Setback limits should aim for a 100-year planning time frame, and also ensure that episodic events are accounted for. The suggested setback limit is therefore two times the average yearly recession rate, times 100"* (NLGS, 2016).

For Point au Mal on the east side of Port au Port Bay, for example, a setback limit would be approximately 125 m based on an average annual erosion rate of 62 cm. Furthermore, these limits *"need to be reviewed at regular intervals in the light of continued data collection, to ensure that the appropriate distance is maintained, in particular in areas of accelerated recession rates"* (NLGS, 2016).

If an unconventional oil and gas development was to proceed in the Port au Port area along the lines discussed in Section 9, all wells would be drilled and completed over a six-year period following exploration. This would see approximately 480 onshore-to-offshore wells permanently placed around the Port au Port Bay area.

The Panel is in agreement with the recommendation Appendix J that:

> *"Development plans for any coastal zone infrastructure, and construction, should include appropriate means and mechanisms for properly decommissioning, removing, or sealing industrial sites after they have reached the end of their useful life"* (Burden, 2016).

These development plans must give particular consideration to the permanent nature of the onshore-to-offshore wells.

Any longitudinal study of coastal change that would provide data in order to assess coastal change over time needs to be implemented immediately in order to provide the best possible information for the selection of sites where permanent infrastructure could be located. As noted by the Geological Survey, *"a minimum of five to ten years of data is normally required for reliable estimates of coastal change"* (NLGS, 2016). Data over such a timeframe does not currently exist for key coastal locations around Port au Port Bay.

Panel Recommendation (PR38): Undertake a Study of Coastal Change Near Potential Infrastructure Sites – Undertake a comprehensive study of coastal change at sites around Port au Port Bay, and other coastal areas, where temporary and permanent infrastructure associated with unconventional oil and gas development may be located. This study would include an analysis of aerial photographs over time and a series of beach/bluff surveys, for example using Real Time Kinematic (RTK) topographic survey technology.

Panel Recommendation (PR39): Require Appropriate Setback Limits for Infrastructure – Determine and require appropriate setback limits, with particular consideration to the permanent nature of well infrastructure, from coastlines that are subject to short-term and long-term changes.

Panel Recommendation (PR40): Conduct Geotechnical Engineering Assessments Prior to Construction of Infrastructure – Undertake thorough geotechnical engineering assessments of all potential locations of well pads and other infrastructure (e.g. gathering lines and product pipelines) to ensure that siting and construction approaches are appropriate.

14.3.5 Other Environmental Considerations

The province does not have specific legislation, regulations, or guidelines focused exclusively on hydraulic fracturing. There are, however, some existing regulatory regimes that address some of the concerns related to hydraulic fracturing, including water use, well integrity, and waste disposal. In some jurisdictions, there is no requirement for public disclosure of fluids used in the hydraulic fracturing process. The Panel believes that public disclosures are critical for any future development. As highlighted in CWN (2015b), *"gaps in Canada's current disclosure practices of data pertaining to hydraulic fracturing prohibit a general consideration of certain risks and best management practices"*.

Should Government decide to proceed with unconventional oil and gas development in Western Newfoundland, it will be critical to build on the experience with the existing offshore oil and gas regulatory regime and to evaluate new requirements to ensure that operators implement industry best practices. This should include a review of the existing environmental impact assessment process.

Panel Recommendation (PR41): Review the Environmental Impact Assessment Process – Review the environmental impact assessment process to ensure that it provides for a comprehensive review of issues unique to unconventional oil and gas development that may not have been considered in processes to date.

Panel Recommendation (PR42): Require Full Disclosure of the Composition of Hydraulic Fracturing Fluids – Require full disclosure to the regulator of additives and concentrations of hydraulic fracturing fluids as part of an approved plan to hydraulically fracture a well; to handle, treat, and dispose of flowback and produced water; and to manage and mitigate the impacts of any spills. Any deviations from an approved plan should require prior approval by the regulator. The regulator should make a disclosure report for each well available in the public domain.

The Panel believes that any unconventional oil and gas development in Western Newfoundland should employ best practices in all aspects of operations, including site development, management, and restoration. Best practices would include, for example, using containment barriers around all equipment utilized during well stimulation, pipelining clean water to sites rather than using trucks, and employing remote monitoring technology to ensure site security and proper operation of producing wells. All exploration, development, production, and decommissioning activities should be carried out under the authority of appropriately licensed professionals. Overviews of industry best practices related to hydraulic fracturing operations are available from the Canadian Association of Petroleum Producers

(CAPP, n.d.), the Petroleum Services Association of Canada (PSAC, n.d.), and the American Petroleum Institute (API, 2012). Best practices in site reclamation and restoration, as discussed in Section 5.7, should be required.

> **Panel Recommendation (PR43): Require Best Practices in Development and Management of Sites and Infrastructure –** Employ standards, licensing and certification processes, and best practices in the development and management of all sites and infrastructure associated with unconventional oil and gas development.

14.4 Health Considerations

One of the most significant concerns expressed by individuals and communities is the potential immediate and cumulative effects on the health of themselves and their children during and after development. As noted in Appendix N, many of the submissions to the Panel raised issues about potential impacts on human health either directly or indirectly (Storey, 2015).

The Panel considered this issue carefully as part of its deliberations and sourced a number of relevant documents and peer-reviewed papers that bear on the issue of human health, which includes both physical and mental health. The Panel sought advice from Dr. David Butler-Jones, previous Chief Public Health Officer of Canada from the University of Manitoba, Dr. Bernard D. Goldstein, a leading authority on public environmental and occupational health from the University of Pittsburgh, and Dr. John R. Bend, a distinguished expert on environmental toxicology from Western University.

Dr. Kevin Keough, a member of the Panel, also prepared a more detailed report of health impacts linked to hydraulic fracturing which is included as Appendix F of this report (Keough, 2016). In addition, the Panel commissioned a review of the relationship between income and health by Dr. Douglas May, a Professor of Economics at Memorial University. This report is included as Appendix G (May & May, 2015).

After considerable study, public and population health experts from around the world have agreed that there is a group of factors, known as the "determinants of health", that have major impacts on health (WHO, 2016) (CPHA, n.d.) (CDC, 2015) (Mikkonen & Raphael, 2010). Any consideration of the impact of a development on human health must take these determinants into account. Health Canada and the Public Health Agency of Canada recognize the following twelve determinants (PHAC, 2011):

- income and social status;
- social support networks;
- education and literacy;
- employment/working conditions;
- social environments;
- physical environments;
- personal health practices and coping skills;
- healthy child development;
- biology and genetic endowment;
- health services;
- gender; and
- culture.

There is general agreement among experts that socio-economic factors comprise about half of the conditions that affect a person's health, with genetics, physical environment, and health services (i.e., the healthcare system) contributing the balance. While the background research on these health determinants was undertaken elsewhere, it would be important to consider local factors to determine their relative importance and impact on people in the context of a development in Western Newfoundland.

The development of an industrial-scale hydraulic fracturing operation along the lines illustrated in Section 9, could lead to degradation of the physical and social environments. Research and commentaries in scientific publications report mostly negative effects associated with hydraulic fracturing operations, a few found that there were no significant positive or negative effects, and fewer still concluded that there were some positive effects.

Those determinants generally considered to have the biggest impact on health status are health services, and personal and community income and wealth. Increasing personal income usually has positive associations with health, whereas lack of income leads to poorer health status.

It will be important for the public and Government to consider evidence and estimates for both possible positive and negative health effects. Any decision to support or permit unconventional oil and gas development must balance the risks and benefits, and the decisions will be impacted by the risk perception and risk tolerance of Government and of members of the public most likely to be affected by such a development.

A number of submissions to the Panel expressed public health concerns and highlighted reports and commentaries that discuss negative health impacts based upon measures of potential toxicants in other regions of North America (Storey, 2015). As discussed in Appendix F, the magnitude of such health effects might be small in comparison to effects from conditions over which individuals have personal control, such as smoking, diet, behaviour, and some social factors (Keough, 2016). Many of the risks arising from unconventional oil and gas development will be specific to a development site and operating procedures.

A smaller number of submissions suggested that potential financial benefits might accrue to the region if unconventional oil and gas development was to proceed in Western Newfoundland. As noted in Appendix F and Appendix G, studies elsewhere imply that there could be positive effects on health. Again, however, local factors influence the benefits from development.

While government policies and regulations can help decrease risks and increase benefits, the Panel believes that any unconventional oil and gas development in Western Newfoundland must be carried out in a manner that protects human health. The remainder of this section includes recommendations intended to protect the health of the people in region where development may occur. It also includes recommendations regarding optimizing positive health impacts by increasing income in the region.

14.4.1 Health Impact Assessment

With any new industrial development of the scale illustrated in Section 9, both negative and positive health effects are possible. As discussed in Appendix F, estimation of any effects on health is best done by carrying out a Health Impact Assessment (HIA) prior to any development (Keough, 2016).

Members of the public, the Newfoundland and Labrador Chief Medical Officer of Health, and other organizations and review bodies noted the need for a thorough examination of the human health effects of unconventional oil and gas development. Consistent with submissions to the Panel and with evidence in the literature, the Panel believes that these effects need to be assessed by performing Health Impact Assessments (NLCMOH, 2015) (NLCAHR, 2015) (OCMOH, 2012) (NSIRPHF, 2014) (Simpson, 2015) (CHPNY, 2014) (MEDACT, 2015) (Keon & Pepin, 2009) (Kibble, et al., 2014) (GCEH, 2011) (Intrinsik, 2014) (IOM, 2014) (Witter, et al., 2013). The submission to the Panel by the Qalipu Mi'Kmaq First Nation Band highlighted the desire to have a particular focus on the impact on children. Qalipu (2016) asks for a focus on:

> *"The impact on the children who would be growing up in close proximity to such an industrial site and the effect it will have on them and future generations, whether it be sociologically, psychologically, physically, and/or medically"* (Qalipu, 2016).

Health Impact Assessments should be carried out with the participation of representatives of the public, industry, and Government working together with independent experts to identify and assess both risks and benefits. Government should underwrite the financial costs of the assessment, and public health experts should be part of the process. The assessment should be performed under the guidance of an independent agent who has the trust of all parties involved. Moreover, it should cover the region that might be developed, such as is envisaged for the Port au Port Bay area as illustrated in Section 9. An assessment might include, among other processes, modelling of impacts on health in the region. Members of the public in the region must play an integral part in the assessment, and their views should carry significant weight. Industry and government experts, particularly those with public health expertise, must participate in the process. More commentary on Health Impact Assessments is provided in Appendix F (Keough, 2016).

Conducting effective Health Impact Assessments requires that there be a significant educational component for participants to increase awareness and understanding of the industrial process and the potential negative and positive influences on health. Health Impact Assessments should be undertaken early so as to inform the decision whether to permit hydraulic fracturing operations. It could lead to the identification of risks and mitigation strategies that could be considered in the development of regulations, development plans, and monitoring strategies. It could also help identify ways in which potential health benefits may be maximized. Health Impact Assessments would identify substantial health risks for which there are currently no effective mitigation strategies, which may lead to a decision to continue the pause on accepting applications for development or it may trigger use of the Precautionary Approach for management of specific risks. Reporting Health Impact Assessment results publicly could be helpful in increasing public confidence.

> **Panel Recommendation (PR44): Complete Health Impact Assessments –** Undertake an independent Health Impact Assessment of any proposed unconventional oil and gas development in Western Newfoundland. The assessment should be for the local region involved in a potential development and must involve representatives of local residents, industry, and Government, together with appropriate experts. Government should provide financially for the assessment and provide access to content experts, but it should not perform or lead the assessment. The results of the Health Impact Assessment should be available in the public domain.

14.4.2 Monitoring

A common concern expressed by individuals, organizations, and public health experts about industrial-scale unconventional oil and gas development is the possibility of substances that adversely affect health being released at various stages of development and operations. Appendix N summarizes these concerns:

> *"In general terms those making submissions were concerned about the implications of exposure to individual elements (air emissions, water pollution, etc.), the cumulative implications of exposure to multiple pollutants (in the air and water and soil, etc.), and the long-term consequences of each of these"* (Storey, 2015).

Potential toxicants include chemicals in the hydraulic fracturing fluids, substances in flowback and produced water, and components of the hydrocarbons released by the stimulation process. Short-term effects could occur through spills during transport of fluids, while longer-term effects could arise from in-ground leakage, most likely in the immediate vicinity of well casings.

An ongoing monitoring system, preferably operating in real-time, should be established to identify and track potential toxicants in air, surface water, and groundwater. The Council of Canadian Academies Panel (CCA, 2014) and the Canadian Water Network (CWN, 2015b) comment on monitoring activities as they relate to human health. Monitoring was also highlighted in other submissions to the Panel and in work completed by, or on behalf of, the Panel (Qalipu, 2016) (OCMOH, 2012) (Gagnon & Anderson, 2015) (Husain, et al., 2016) (Lahey, 2016).

It is recognized that, at present, a number of potential toxicants, such as some radionuclides, cannot be measured in real-time. Nonetheless, they should be recorded and reported without delay. Possible toxicants should be tested at strategically-chosen sites in and around operations as guided initially by experiences elsewhere. The required testing must consider the compositions of hydraulic fracturing fluids, flowback and produced water, and the oil and gas that are produced. The monitoring system would need to adapt over time to measure additional substances as more is learned during operations. The full composition of flowback and produced water can only be determined after operations start.

A monitoring system will have little benefit in the absence of a reliable set of baseline measurements from which deviations that occur during operations can be measured (CWN, 2015b). Public confidence may increase if the results of monitoring are maintained and updated in an easily accessible on-line database that is available to the public.

> **Panel Recommendation (PR45): Monitor and Publicly Report the Impacts of Released Toxicants on Human Health –** Establish an ongoing, real-time monitoring system, including interpretation of the data collected, with strategically selected sites to measure potential toxicants released into the environment. Ensure that baseline measurements at the sites are completed in advance of industrial activity. The data should be interpreted periodically by appropriate health experts to assess the potential impact on human health. The data and the interpretation should be available in the public domain.

14.4.3 Composition of Fluids

As discussed in Appendix H (Gagnon & Anderson, 2015) and Appendix M (Lahey, 2016), increasingly jurisdictions require public disclosure of chemicals that are used in hydraulic fracturing fluids. While exceptions to disclosure are permitted for chemicals that are trade secrets, full disclosure to government officials and health professionals is required under certain circumstances (CCA, 2014). The Nova Scotia Independent Review Panel recommended that:

> *"Companies should be obliged to place records of all chemicals used in hydraulic fracturing (including identities, concentrations, quantities and toxicity data) in the public domain"* (NSIRPHF, 2014).

If unconventional oil and gas development is to proceed in Western Newfoundland, it will be important that the composition of fracturing and all waste fluids be available to regulatory, monitoring, and health authorities. A similar requirement is essential for composition of the hydrocarbons produced. Timely access to composition information must be available to health professionals who might be treating patients for illnesses or syndromes of suspected environmental origins. Notwithstanding the desire for some companies to protect the composition of their fracturing fluids, it is essential that human health take precedence over company proprietary information.

> **Panel Recommendation (PR46): Ensure Access by Health Professionals to Compositional Information for all Fluids Used or Produced –** Make it a condition of licensing that the compositions of all fluids used or produced during hydraulic fracturing operations are available to the regulator and to monitoring and health authorities. Timely access to compositional information must be provided to health professionals to enable proper treatment of patients with illnesses from suspected exposure.

14.4.4 Best Practice in Regulation

As discussed in Appendix M, *"the regulation of hydraulic fracturing is intended to protect the environment and human health"* (Lahey, 2016). Therefore, it is essential that policy makers, regulators, and all parts of industry adhere to the highest standards over the life of the development. Standards for practice should be set, monitored, and enforced by the regulator in light of the best-available evidence from other jurisdictions and data relevant to the local environment.

In a submission to the Panel, the Chief Medical Officer of Health for Newfoundland and Labrador proposed two elements of a regulatory framework that are necessary for any industrial development having *"broad undefined health impacts on a population"* (NLCMOH, 2015). These elements include:

- *"The protection of human health as specific priority in regulations and the process governing the approval of future developments; and*
- *Proposals undergoing environmental assessment include a specific requirement for local-level health impact and/or risk assessment"* (NLCMOH, 2015).

As local knowledge is gained, it would be appropriate to modify standards and regulations accordingly. Standard setting should incorporate input from the various segments of the industry together with advice from environment and public health experts from outside the industry. Respect for population and public health perspectives is essential for protecting health status and for optimizing the potential benefits to health status from financial gains in the local community.

Appendix M documents the importance of institutional arrangements that focus on protecting human health and the environment (Lahey, 2016). While in many jurisdictions, the role of the Minister of Environment and his/her department is defined with respect to regulation of hydraulic fracturing operations, the same formal role is not normally defined for the public health system.

Appendix M includes a discussion on the importance of regulations reflecting all relevant perspectives (Lahey, 2016). Being fully transparent may help the public develop confidence that the regulator is acting in the best interests of their health.

> **Panel Recommendation (PR47): Engage Public and Population Health Experts in Setting Standards and Regulations –** The regulator must establish, monitor, and enforce regulations and standards for all aspects of unconventional oil and gas development that are based upon the best-available evidence from other jurisdictions and that take local factors into account. Public and population health experts must be involved in setting standards and regulations.

14.4.5 Adaptive Management

While information on potential benefits and risks for health of a large-scale unconventional oil and gas development can be gleaned from other jurisdictions, the actual magnitudes of either benefits or risks will depend on many local physical, environmental, socio-economic, and operational factors. Over time, those factors and the resulting benefits and risks could change. It is incumbent on the regulator and the industry to practice Adaptive Management (USDOI, 2009), supplemented with the Precautionary Approach as appropriate, to optimize the balance of benefits and risks over the duration of the project. Public health authorities must be involved. As discussed in Appendix M:

> *"This approach depends upon continuous engagement with stakeholders, industry-wide networks through which learnings are shared and robust two-way relationships between industry and researchers"* (Lahey, 2016).

Transparency about all aspects of the development, including potential benefits and risks, by the operator and the regulator is essential to building confidence and more positive relationships with people in the region of a potential development.

> **Panel Recommendation (PR48): Require Transparency in Adaptive Management –** Ensure that adaptive management of a project is practiced by the regulator and the operator and that transparency about risks and benefits and the factors affecting them is maintained at all times.

14.4.6 Realizing Health Benefits

A large-scale hydraulic fracturing project, such as that envisaged by the scenario discussed in Section 9, could, under appropriate circumstances, bring increasing income and wealth to the local area. Appendix F (Keough, 2016) and Appendix G (May & May, 2015) document the well-known association between income and health.

Government needs to take steps to ensure that those bearing the higher health and other risks from a development also have a reasonable opportunity to share in the wealth generated. This objective could be met by Government imposing conditions that would increase benefits beyond those that would normally occur. For example, a local benefits agreement could require or incentivize enhanced local employment and revenue sharing with local communities. Government could require that the operators employ a minimum number of local people in the more highly-paid positions and support the training of local people to meet these goals.

Positive influences on health can be expected when there is sustained positive change in income and employment. For example, young children might have a healthier start in life if their family income is raised. The health status of adults has been positively correlated with income and a number of other social factors, such as social status, education, and employment status, each of which should improve over time. On the other hand, increased disparity in income and health status is possible if benefits accrue only to a small segment of the community. Positive health effects are much more likely if Government requires that there be a variety of significant local benefits, and if steps are taken to ensure that all people in the community can access benefits of some form.

> **Panel Recommendation (PR49): Require Development Plans to Demonstrate Substantial Local Benefits –** Ensure that there are substantial local benefits that are accessible across the socio-economic spectrum to realize health benefits from unconventional oil and gas development.

14.4.7 Improving the Ability to Respond to Health Impacts

With respect to existing capacity for health services in Newfoundland and Labrador, a submission by the Roman Catholic Religious Leaders states:

> *"The health system in Newfoundland and Labrador at the present time is stretched to find adequate financial and human resources to respond to current health needs"* (RCRL, 2015).

Similar concerns were also expressed to the Panel about overstressing the existing healthcare system (WCHCAC, 2015) (CHPCBA, 2015). With respect to the anticipated public investment that would be needed to adequately deal with mitigating health impacts, concerns were expressed with regard to the province's *"ability to provide the financial resources needed to create the infrastructure, capacity, and processes to carry out the targeted and strategic actions needed to prevent and mitigate the negative health impacts of hydraulic fracturing in the province"* (RCRL, 2015).

There will be individuals who are unable to take advantage of the positive aspects of development. Government would need to provide special assistance and support to such individuals.

There are additional concerns about the possibility of negative effects from what is sometimes called the "boomtown effect" that can occur when there is a rapid and substantial increase in the number of highly paid, and often, young workers (NLCMOH, 2015) (RCRL, 2015). The boomtown effect is also discussed in the reports of other Canadian panels (NSIRPHF, 2014) (CCA, 2014). This effect usually occurs in the early development stages of resource-based industries, or industries that rely on a large transient workforce. The negative aspects include increases in accidents, violence, and venereal diseases. A subtle negative effect could be stress felt by some people who are anxious about the adverse effects that might result from development.

The healthcare and social services systems serving a region where a boomtown effect is felt can be stressed as a result of *"increased demand for public services, including policing, social services, healthcare, and local government services"* (NLCMOH, 2015). Enhancements to the healthcare and social services systems serving a region will help reduce these risks. The Panel believes that a comprehensive review of the healthcare, fire and emergency services, and social services systems serving the region of any potential unconventional oil and gas development must be carried out in advance of development in order to identify and correct any deficiencies in the systems.

First responders, physicians, and other health professionals will require education and training to recognize medical conditions that might occur as a result of environmental exposure to chemical agents used in hydraulic fracturing operations. Environmental health experts should provide the education and training for these groups.

Panel Recommendation (PR50): Review the Healthcare and Social Services Systems – Undertake a comprehensive review of the healthcare and social services systems to identify any deficiencies in the ability to respond to increased demands associated with unconventional oil and gas development.

Panel Recommendation (PR51): Ensure Appropriate Resources for the Healthcare and Social Services Systems – Ensure that healthcare and social services systems are resourced to be able to respond to increased demands associated with unconventional oil and gas development.

Panel Recommendation (PR52): Ensure Appropriate Support for First Responders and Health Professionals – Provide education, training, and support for first responders and health professionals to enable them to recognize and treat conditions that might arise through environmental contamination during development.

The boomtown effect may also be reduced through appropriate monitoring; active engagement of community support systems, such as social services and law enforcement; and broad-based education about health risks in the population.

Panel Recommendation (PR53): Ensure Appropriate Resources for Public Heath Education and Community Support – Ensure that high quality information about public health is available and that there is appropriate resourcing and engagement of community support systems, including law enforcement.

Public health officials should monitor regional and local health data on a regular basis. A useful and immediate means of determining ongoing health status would be to establish a cohort of individuals who are representative of the population in a development area, and monitor that cohort regularly, at least yearly, over a substantial period using a fixed set of health tests. This cohort should be tested, in advance of unconventional oil and gas development, to establish a baseline for health status. This process would contribute information that would important for adaptive management of projects by the regulator and the operators.

Panel Recommendation (PR54): Require Ongoing Monitoring of the Health Status of People Living Near a Development – Monitor the physical and mental health status of the local population using standard reporting mechanisms, and proactively establish a cohort representative of the local population that is monitored regularly for health status over an extended period.

14.5 Regulatory Considerations

To assess regulatory approaches in other jurisdictions and to identify regulatory best practices, the Panel engaged the assistance of Professor William Lahey of the Schulich School of Law at Dalhousie University who has expertise in areas of law, regulation, and policy pertaining to the environment, energy, and healthcare. Professor Lahey's report is included as Appendix M of this report (Lahey, 2016).

An effective regulatory framework would include *"appropriate science-driven, outcome-based regulations with strong performance monitoring, inspection, and enforcement"* (CCA, 2014). The Panel believes that such a framework, including appropriately resourced and empowered monitoring and enforcement capacity, is critical to ensuring that oil and gas operations are carried out in a safe and responsible manner.

The regulatory framework should minimize risk to a level where there is confidence that the operations are "safe" from health and environmental perspectives. It is important to clarify that "safe" does not mean that it is possible to ensure that nothing can go wrong. As noted in Appendix M, *"hydraulic fracturing is the same as other regulated industrial activities" which are "regulated because of their potential to cause harm"* (Lahey, 2016). It is unrealistic to expect that a regulatory system can prevent all harm from occurring.

The potential harms arising from industrial activity need to be understood. The regulatory system must be structured in such a way as to provide "appropriate" oversight and responsibility. In such a context, "appropriate" may be understood to mean proportionate to the potential harms. As recommended in Appendix M, since the potential harm from hydraulic fracturing operations could be significant if not appropriately regulated, for some parts of the operations regulations *"should be defined in a precautionary way"* (Lahey, 2016). In establishing the proportionality of the regulations, it is also important to reflect the *"level of protection reasonably expected by the public and especially by those most likely to be adversely affected if potential harms are not prevented, minimized, or mitigated"*.

Appendix M presents a review of the regulatory oversight mechanisms in other relevant Canadian jurisdictions (i.e., Alberta, British Columbia, and New Brunswick) for various aspects of hydraulic fracturing operations (Lahey, 2016). Lahey (2016) also provides a comparison with the current regulatory framework in Newfoundland and Labrador, an overview of best practices to ensure appropriate oversight of hydraulic fracturing operations, and recommendations with respect to actions/regulations and best practices that ought to be considered by Government should unconventional oil and gas development be permitted. Lahey (2016) also reviews the proposed "Guidelines" document that was provided to the Panel by Government at the outset of the review process (Precht & Dempster, 2014b).

14.5.1 Regulatory Readiness and Capacity

The Panel is in agreement with Lahey (2016) that a detailed and comprehensive regulatory approach is needed since the risks could cause significant harm if they *"are not effectively controlled"*. The Panel also agrees that:

> *"The more specific and serious risks in question, such as the migration of gas or chemicals from wells to groundwater, can be controlled by specific measures, many based on sound engineering principles, that can be specified with a reasonably high level of precision"* (Lahey, 2016).

Effective regulation of hydraulic fracturing operations will require an effective command and control regulatory framework within which the command component corresponds to *"a permit, licence, or approval that specifies the terms and conditions on which approval is granted"* (Lahey, 2016). The control component *"is the various measures that are taken both by the regulated operator and the regulator to ensure the activity is conducted as approved"*.

As discussed in Appendix M, the Newfoundland and Labrador's regulatory framework is *"broadly comparable to that which is already operational in Alberta and British Columbia and that has been developed for New Brunswick"* (Lahey, 2016). Furthermore, Lahey (2016) states that implementation of the guidelines (Precht & Dempster, 2014b) would strengthen the alignment between the framework in the province and in other Canadian jurisdictions where there are hydraulic fracturing operations.

Lahey (2016) points out that in both Alberta and British Columbia, the regulatory approach is shifting away from project-based regulation to play-based regulation that is more focused on regulating in the context of the overall geological formation that is the focus of development. Increasingly, regulation is also including performance-based elements that require proponents to achieve specified goals or outcomes rather than simply complying with prescribed rules. A performance-based approach can *"better accommodate the up-to-date expertise those in industry may have"* (Lahey, 2016). Prescriptive regulations continue to be appropriate for some critical areas, such as well integrity.

In a play-based regulatory context, multiple operators collaborate to develop a play development plan that achieves the required regulatory outcomes. As discussed in Appendix M, this represents a shift to regional and performance-based regulation in which operators are *"expected to develop the plan with public input and to include in the plan processes for continuing engagement and relationships with the community"* (Lahey, 2016).

Appendix M also highlights some best practices in relation to the regulation of unconventional oil and gas development along with considerations that would be appropriate in the course of building a regulatory framework in advance of permitting development (Lahey, 2016). The Panel is of the opinion that these best practices and considerations should be reviewed carefully by Government and acted upon if there is to be further development of a regulatory system for unconventional oil and gas development in Western Newfoundland.

While Appendix M includes further details regarding best practices and considerations, the Panel is in agreement with the following recommendations related to ensuring regulatory readiness and capacity.

Panel Recommendation (PR55): Review Best Practices from Other Jurisdictions in Developing a Regulatory Framework – Consider and build upon the expertise and experience of jurisdictions that have the most experience in building and administering a comprehensive regulatory framework for unconventional oil and gas development. This does not mean that other frameworks should be blindly adopted, but, where relevant work has been done elsewhere, this should be leveraged and modified to deal with any required variation associated with local environmental, health, socio-economic, and geological factors.

Panel Recommendation (PR56): Establish a Comprehensive Regulatory Framework – Ensure that a comprehensive regulatory framework, which includes an appropriate mix of performance-based and prescriptive regulation, is in place before unconventional oil and gas development is permitted and provide for the evolution of regulations as new knowledge is gained. This will provide for a higher level of confidence that concerns are being addressed through regulations and monitoring while offering clarity to proponents about the ground rules for development.

Panel Recommendation (PR57): Provide for Meaningful Public Participation in Decision-Making – Ensure that the regulatory framework provides opportunities for those potentially affected by a proposed development to participate, for example through formal consultation, in the regulator's decision-making process. This is in addition to, and separate from, the requirement for proponents to demonstrate effective community engagement throughout a project.

Panel Recommendation (PR58): Provide Appropriate Resources to Ensure Effective Regulation – Ensure that the regulatory framework is appropriately resourced, including the necessary resources to provide effective oversight and monitoring, before unconventional oil and gas development is permitted. This will lead to confidence that matters of concern are being addressed through regulations and monitoring and will offer clarity to proponents about the ground rules for development.

Panel Recommendation (PR59): Implement a Program for Monitoring the Effects of Development – Ensure that regulations require a comprehensive and effective program for monitoring the effects of unconventional oil and gas development, including cumulative health and environmental effects, to be in place prior to commencement of development, with provision for halting development when necessary to prevent irreversible harm.

Panel Recommendation (PR60): Implement a Waste Management Program – Ensure that regulations require a comprehensive and effective waste management program to be approved for all waste associated with unconventional oil and gas development.

14.5.2 Regulatory Oversight

In addition to effective regulatory readiness and capacity, it is critical that the province have effective regulatory oversight of the industry. It is also critical that industry fully complies with its regulatory responsibilities. Furthermore, there should be significant consequences as a result of serious breaches of responsibilities. In addition to financial penalties as remedies in the event of a breach of responsibility, revoking authority to operate or denying future approvals are also consequences that may be warranted in some circumstances. A number of recommendations follow related to regulatory oversight and compliance.

Panel Recommendation (PR61): Require Licenced Professionals and Companies for All Engineering and Geoscience Work – Require that all future engineering and geoscience work, including reviews and assessments associated with unconventional oil and gas development, be carried out by individuals and companies that are licensed to practice and operate in Newfoundland and Labrador. Such professionals and companies would be subject to standards for competence and ethics under the regulation of the Association of Professional Engineers and Geoscientists of Newfoundland and Labrador.

Panel Recommendation (PR62): Involve Public Health Officials in Developing Regulations and Monitoring – Require that public health officials be involved in developing regulations and in monitoring for potential environmental and health impacts.

Panel Recommendation (PR63): Communicate Regulatory Requirements Clearly – Communicate regulatory requirements in a style, form, and medium that best facilitates an understanding of the regulations by those most immediately responsible for compliance with them.

Panel Recommendation (PR64): Engage Stakeholders in the Review and Continuous Improvement of Regulations – Work with representatives of communities, environmental organizations, public health officials, other economic sectors, academia, and society more generally, to provide effective mechanisms to advise industry and the regulator on the adequacy and effectiveness of regulations, and on improvements to regulations and the regulatory process, including compliance and enforcement.

Panel Recommendation (PR65): Ensure the Regulator has Access to Information About the Status of Each Well – Ensure that the regulator has continuous access to the critical data on the status of work taking place under regulatory approvals at all stages of each well's life cycle, from initial drilling to abandonment and capping, including any post abandonment obligations that may be placed on operators.

Panel Recommendation (PR66): Engage Independent Experts in the Review of Information Provided by Industry – Require that the assessments, evaluations, and plans that proponents and operators are required to provide, including those related to community engagement, are completed, validated, and certified by independent third party experts, as appropriate.

Panel Recommendation (PR67): Engage Independent Experts in the Review of Monitoring Data and Evaluations – Require validation or certification, as appropriate, by qualified and independent third parties of the results of broader monitoring of impacts, including environmental and health monitoring, and of performance against standards and objectives, including objectives for community engagement.

Panel Recommendation (PR68): Provide Adequate Resources for Monitoring – Ensure that adequate resources for regulatory compliance monitoring, and environmental and heath monitoring are provided.

14.5.3 Regulatory Transparency and Continuous Improvement

The Panel feels that it will be important to establish regulatory transparency, with continuous improvement built into the regulatory framework. This would reflect the view that regulation is a form of public administration for which openness and transparency are core values. As discussed in Appendix M, transparency and continuous improvement help *"ensure that regulators are accountable for protecting the people and things they are legislatively mandated to protect"* (Lahey, 2016). As noted by Lahey (2016), and highlighted in various submissions to the Panel, the independence of the regulator and regulatory process is critical to both the legitimacy and credibility of the regulatory process. A number of recommendations follow to deal with regulatory transparency and continuous improvement.

Panel Recommendation (PR69): Support the Ongoing Research Needed for Improvement in Regulation – Ensure that the regulator actively seeks opportunities to support the research that is needed to improve the understanding of the risks associated with hydraulic fracturing operations, to improve the effectiveness of measures that are used to manage risks, and to improve upon regulatory measures.

Panel Recommendation (PR70): Complete a Regular Independent Review of Regulations – Ensure that there is regular review and evaluation of regulations related to unconventional oil and gas development that is done arms-length from the regulator and that follows an open and transparent process that seeks and considers input from all parties with a direct interest in the effectiveness of the regulations in achieving the desired regulatory outcomes.

Appropriate resources for monitoring and interpretation of data are critical to the effectiveness of implementation of a regulatory framework. Monitoring and interpretation are key to understanding what impact the industry is having on matters of public health, environment, and public safety. In addition, monitoring and interpretation can bring early attention to systemic or cumulative problems, and provide important information for assessing the effectiveness of community engagement plans. Furthermore, effective monitoring and interpretation are required to evaluate the effectiveness of regulations and enforcement and to strengthen regulations. As discussed in Appendix M, monitoring also provides essential data to support research *"to answer the unknowns that currently exist as to the effectiveness of*

industry practices and of the engineering, structural, managerial, and operating requirements which regulation currently applies" (Lahey, 2016).

The process includes baseline and cumulative effects monitoring; data interpretation; and public reporting of health, social and community impacts, gas emission impacts, air quality impacts, soil and land impacts, seismicity impacts, and surface and ground water quality impacts. The need for such data, interpretation, and reporting has been highlighted in other recent Canadian reports pertaining to unconventional oil and gas development (CCA, 2014) (NSIRPHF, 2014) (NBCHF, 2016) (CWN, 2015b). The public reporting of various data elements is also captured in discussions and recommendations elsewhere in this report.

> **Panel Recommendation (PR71): Develop Comprehensive Monitoring Regulations –** Ensure that there are comprehensive regulations implemented related to environmental, health, and seismicity monitoring, including requirements for establishing relevant baseline data, for interpreting the collected data, and for making the data and interpretation available in the public domain. This should also include ongoing monitoring of the effectiveness of community engagement plans.

> **Panel Recommendation (PR72): Involve Researchers in the Design, Governance, and Evaluation of Monitoring Programs –** Include researchers in the design, governance, and evaluation of monitoring programs to ensure that monitoring produces the data needed for the research that will improve monitoring and interpretation over time.

> **Panel Recommendation (PR73): Implement Continuous Monitoring and Interpretation Processes –** Structure monitoring and interpretation processes to be continuous throughout and beyond the lifetime of approved projects, adjusting the scale and methods for monitoring and interpretation to the level of corresponding risks.

> **Panel Recommendation (PR74): Clarify the Responsibilities of Different Parties for Monitoring and Interpretation –** Ensure that the responsibilities of Government, the regulator, and industry with respect to monitoring and interpretation are well-defined in regulations and are communicated clearly, including to the public.

> **Panel Recommendation (PR75): Implement Transparent Monitoring and Interpretation Processes –** Ensure that the monitoring and interpretation processes are implemented and are transparent, openly conducted, and include the public disclosure of the results. Require, support, and enable certified independent third party involvement in monitoring and interpretation.

14.5.4 Regulatory Jurisdiction

As discussed extensively in Appendix M, there are jurisdictional issues that are interrelated with regulation of unconventional oil and gas development (Lahey, 2016). Models to regulate an industry may be established, either independent of, or within, Government. Lahey (2016) refers to these models as the "commission model" and the "government department model". Examples of the commission model are the Alberta Energy Regulator (AER) and the British Columbia Oil and Gas Commission (BCOGC), while New Brunswick is considering regulation through two government departments.

As proposed in Appendix M, the commission model is more likely to see the development of regulatory expertise and engagement of specialists that *"may be less likely to work in, or be retained by, a government department"* (Lahey, 2016). The commission model is also helpful in ensuring *"regulatory decisions are made for regulatory reasons, rather than for broader policy or political reasons"*. Other advantages of the commission model include creating separation between regulatory responsibility and economic considerations, and reducing *"the risk of regulatory fragmentation"*.

Appendix M highlights some disadvantages of the commission model which include *"regulatory capture due to its strong associations with the regulated industry and membership of regulators and those in the industry in the same professional communities"* (Lahey, 2016). There are also concerns with respect to decision-making related to regulation and decision-making related to policy *"working at cross purposes"*.

As illustrated in Section 9, development of the Green Point shale is expected to involve onshore-to-offshore wells, with most of the operations carried out onshore. This onshore activity would come under the current jurisdiction of various provincial government departments. These would include the Department of Natural Resources, the Department of Environment and Conservation, and Service NL, which has authority for worker health and safety through the Occupational Health and Safety Branch. Offshore aspects of operations would fall within the jurisdiction of the C-NLOPB.

This regulatory framework is consistent with the combined commission and Government department model suggested for unconventional oil and gas development in Western Newfoundland (Precht & Dempster, 2014b). As noted by Lahey (2016), however, "this could make the integrated and seamless regulation that effective regulation of fracturing clearly requires more difficult to accomplish". Lahey (2016) goes on to state:

> *"It could result in jurisdictional uncertainty and arguments, regulatory gaps, regulatory duplication and overlap, and conflicting direction to operators. More generally, it could result in a regulatory system which is less efficient and less effective than a regulatory system under a single regulatory authority, at least for the oil and gas component of regulation, would be".*

Regulation of well operations would straddle jurisdictional boundaries and, without careful coordination among regulatory authorities, could be subject to the regulatory gaps noted in Appendix M (Lahey, 2016).

Concerns about regulatory jurisdiction from a proponent's perspective were submitted to the Panel (Shoal, 2015d). In particular, concerns were expressed about regulation under multiple jurisdictions, and it was suggested that *"reporting to regulators in two different jurisdictions is inefficient and at times unworkable"*. Furthermore, it was noted that neither the C-NLOPB, which has significant experience regulating conventional offshore oil and gas activity, nor the province, which has more limited experience in regulating conventional onshore oil and gas activity, have experience in regulating unconventional oil and gas activity (Shoal, 2015d). Concerns about jurisdictional matters and regulatory fragmentation also feature in a number of public submissions received by the Panel (SOSS, 2015) (PPBFC, 2015) (RCRL, 2015) (WEC, 2015).

Fragmentation of regulatory responsibility among different regulators was identified as a major concern by the Montara Commission of Inquiry report (Borthwick, 2010), which followed from a 2009 blowout from the Montara Wellhead Platform approximately 250 km off the coast of Western Australia. The Commission asked *"was the oversight of their [the operator's] operations by regulators diligent?"* As a result of the inquiry, the Commission recommended *"establishing a single independent authority, with a properly functioning Board, which would be responsible for safety, well integrity, and environmental plans"* (Borthwick, 2010). At the time of the blowout, both national and state regulators carried out regulation of offshore oil and gas operations. The Commission concluded that *"under these arrangements well integrity issues did not receive [the] necessary priority, thereby prejudicing safety and environmental objectives*".

With respect to consolidating the regulation of onshore-to-offshore oil and gas activity under a single regulator, Appendix M states:

> *"For constitutional and intergovernmental reasons, it would probably not be possible to do this by expanding the authority of onshore regulators to the offshore"* (Lahey, 2016).

It may be feasible, by agreement of both the provincial and federal governments or by changes to legislation, to *"expand the authority of the C-NLOPB to the onshore"* (Lahey, 2016). As suggested in Appendix M:

> *"This would bring the regulatory experience and expertise of the Board to bear on the regulation of onshore hydraulic fracturing and thereby help to ensure it was knowledgeably regulated from its very beginning. To the extent the Board has earned the trust and confidence of the public, it would contribute to public trust and confidence in how onshore development will be regulated"* (Lahey, 2016).

Consolidating regulatory authority under the C-NLOPB, however, also has issues that would need to be resolved. These include developing expertise and regulations to address issues associated with onshore-to-offshore unconventional oil and gas development that are not subject to existing regulation of the offshore industry. The onshore context for unconventional oil and gas development in Western Newfoundland would be very different from the offshore context in which the C-NLOPB currently has experience.

The administration of regulations pertaining to unconventional oil and gas development in Western Newfoundland, including consolidating the regulations under a single regulator, requires cooperation between the federal and provincial governments. Under the Canada – Newfoundland and Labrador Atlantic Accord Implementation Act, Section 46.1 provides for the C-NLOPB to enter into memoranda of understanding with the provincial government in order to *"ensure effective coordination and avoid duplication of work and activities"* (CNLAAIA, 2015). Under Section 137.1, the C-NLOPB can delegate some of its authority related to regulation. This provides scope for regulatory coordination between the province and the C-NLOPB. Relevant provincial legislation also needs to be coordinated with the federal government for matters under provincial legislation. For example, Sections 72 and 73 of the Newfoundland and Labrador Environmental Protection Act make provisions for agreements among governments with respect to environmental reviews and for joint reviews to be undertaken (NLEPA, 2014).

While it is beyond the scope of the work of the Panel to develop a specific regulatory framework, the Panel believes that a single regulatory body should have the authority, either by legislation or through delegation or memoranda of understanding as provided for in existing legislation, for unconventional oil and gas development in Western Newfoundland. In reflecting a regulator's primary role of protecting the environment, public health, and worker health and safety, the regulatory framework must be established with appropriate arrangements with the Department of Environment and Conservation, the Department of Health and Community Services, the Occupational Health and Safety Branch of Service NL, the Department of Natural Resources, and the Canada – Newfoundland and Labrador Offshore Petroleum Board.

Panel Recommendation (PR76): Establish a Single Regulator – Establish a single regulator for unconventional oil and gas development, including onshore-to-offshore operations, in Newfoundland and Labrador.

14.5.5 Abandoned Well Program

There needs to be an abandoned well program that has the financial and technical capacity to complete the abandonment and remediation of wells that have been abandoned prior to completion of the required decommissioning and abandonment procedures. Wells that have been abandoned in accordance with regulations but develop leaks or other loss of integrity after abandonment or remediation also need to come under this fully-resourced program.

Recently, the Government of Saskatchewan proposed an Accelerated Well Cleanup Program for *"decommissioning and reclamation of 1000 non-producing wells"* at a total cost of $156 million or an average of $156,000 per well (SASK, 2016). The proposed reclamation process includes an *"environmental site assessment, the safe removal and disposal of equipment, the restoration and re-contouring of the site, and the re-vegetation of the land"*. Also, in March 2016, the

Petroleum Services Association of Canada made a request to the federal government for $500 million in support of well decommissioning operations in Alberta (PSAC, 2016b). In Alberta, the Orphan Well Association (OWA) works under the authority of the Alberta Energy Regulator (AER) to deal with an "orphan", which is a *"well, pipeline, facility or associated site which has been investigated and confirmed as not having any legally responsible or financially able party to deal with its abandonment or reclamation"* (OWA, 2015b).

The 2014/15 Annual Report for the Orphan Well Association notes that the total revenues of the OWA since 1997 have been approximately $239 million (OWA, 2015a). This includes just over $30 million in funding from the Government of Alberta, with most of the balance of funding coming from levies and fees paid by the producers of oil and gas in Alberta.

The total expenditure on abandonment, remediation, and enforcement since 1997 has been approximately $215 million plus an additional $7.7 million in administration. At the start of 2015/16, the OWA had a surplus of approximately $17.5 million, including $15 million from payment by the oil and gas industry for the year's activities and approximately $2.5 million in operating surplus.

The OWA does not appear to have been structured to pay for remediation work that will be necessary when the industry is no longer operating in Alberta. The fund administered by the OWA carries very little funding forward, and the immediate work of the OWA depends entirely on the contributions from the most recent levy. In 2014, the OWA had $16.2 million in revenue and approximately $16.6 million in expenditures (OWA, 2015a).

With low oil prices and instability in the Alberta oil and gas industry, the number of companies going out of business has increased, resulting in an increase in the number of abandonments. The OWA only has the capacity to do work while there are operating companies contributing to the fund. As costs go up (due to increased abandonments) and the number of operating companies go down (as some players exit), the companies that remain have to pay higher levies to maintain or grow the fund to meet the demand. As noted in Appendix D, *"sometimes regretfully, delaying well decommissioning for cost reasons can also delay rehabilitation"* (Dusseault, 2016).

While the OWA currently has approximately 700 orphan wells in its inventory (OWA, 2015a), it is estimated that *"as of January 2016, Alberta had more than 75,000 inactive wells on record requiring downhole wellbore abandonment and surface reclamation, a process called well decommissioning"* (PSAC, 2016b). The total investment required for acceptable well decommissioning is estimated to *"range between $8 and $82 billion"*.

It is clear that the OWA is not structured to respond to much more than the very short-term issues of unexpected well abandonment by its contributing companies. Recent proposals to the federal government by the Government of Saskatchewan (SASK, 2016) and by the Petroleum Services Association of Canada (PSAC, 2016b) identify factors beyond the control of industry (i.e., low oil prices) that result in an increase in the number of abandoned wells. This implies that, in the long term, the cost for remediation of abandoned wells ultimately will be borne by the public in the absence of a sustainable well abandonment fund that has the financial capacity to cover future clean-up costs.

Wellbore leakage of methane in provinces that have active onshore oil and gas drilling operations are common (Dusseault, et al., 2014). While high leakage rates are reported in some provinces, the majority of the leaks are considered to be minor in nature. There are, however, a small number of leaking wells that emit much larger volumes of methane. These so-called "superemitters", which tend to have leaks that are easier to detect, are usually the focus of remediation efforts.

A recent study concluded that between 0.7% and 9.1% of oil and gas wells drilled in Pennsylvania from 2000-2012 have some compromising of the cement or well casing integrity (Ingraffea, et al., 2014). It is estimated that approximately 4% of the wells in Alberta are slowly leaking gas (CCA, 2014). This only reflects those wells where leaks at the surface have been detected and some of them measured. There remains a gap in information about possible

seepage into the subsurface (CWN, 2015b). Well integrity is discussed in more detail in Section 11.4 and Appendix D (Dusseault, 2016).

The long-term problem of leaky wells may not worsen with time provided that the primary cementation is done properly and that the abandonment is executed with care and due diligence. When steel and cement deteriorate, the volume of the debris is larger than the volume of the intact material. This volumetric expansion serves to block additional fluid flow.

There remains, however, a need for a better understanding of the long-term structural integrity and behaviour of oil and gas wells. Old wells had much less quality control and utilized inferior construction methods compared to wells constructed today. As part of any pilot drilling, completion, and stimulation program that may be carried out in the Port au Port Bay area, there should be a rigorous well monitoring and interpretation program that provides longitudinal information about well integrity. This could guide future decisions about long-term management of abandoned wells. To minimize legacy issues arising from drilling of oil and gas wells, it is important that *"the appropriate financial and monitoring processes are in place, particularly after well abandonment"* (Davies, et al., 2014).

Panel Recommendation (PR77): Implement a Well Integrity Monitoring Program – Develop and implement a monitoring and interpretation program to assess well integrity coincident with the pilot well activity to reduce the risk of well integrity problems and to ensure that appropriate well completion programs are implemented. Information from this monitoring program should be available in the public domain for use by researchers working on techniques to improve well integrity.

Panel Recommendation (PR78): Implement an Abandoned Well Program – Ensure that an effective "abandoned well" program is established with the financial capacity to cover future costs associated with regular monitoring and remediating of any wells that encounter integrity issues post-abandonment, including the need to remediate wells into perpetuity.

14.5.6 Financial Security

Appropriate financial security is required of the operator to ensure that there is sufficient financial capacity to deal effectively with spills, leaks, or other incidents that may occur during exploration, development, or production operations. It is important to recognize that in February 2016, the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) adopted more stringent financial security guidelines for offshore oil and gas developments (CNLOPB, 2016). These guidelines were developed jointly by the C-NLOPB, the National Energy Board (NEB), and the Canada-Nova Scotia Offshore Petroleum Board (C-NSOPB) to clarify the financial requirements set out in various Acts and Regulations related to offshore oil and gas development. The offshore component of any unconventional oil and gas development in Western Newfoundland would be encompassed by these legislative and regulatory changes.

The revised financial security requirements embody the "polluter pays" principle (CNLOPB, 2016). They are designed to ensure that companies operating in Newfoundland and Labrador's offshore area have the financial ability to respond appropriately and effectively to an incident (e.g., an oil spill or leak), and to pay for all actual costs, losses, or damages incurred as a result of an incident, including by the C-NLOPB, in dealing with an incident.

The financial requirements are comprised of three components (CNLOPB, 2016):

- absolute liability;
- financial responsibility; and
- financial resources.

In the context of the revised legislation and regulations, the absolute liability specifies that operators are liable for the loss or damage that they may cause as a result of an incident, regardless of negligence or fault, for losses up to certain limits set out in legislation. Currently, the limit for absolute liability in the Newfoundland and Labrador offshore is $1 billion for exploration, development, production, decommissioning, and abandonment activities.

The second component of the financial requirement, the financial responsibility, is an obligation imposed upon the operators which guarantees that the C-NLOPB has immediate access to funds in the event of an incident. The amount of funding that the operator must have available depends on the oil and gas activity being undertaken. For drilling, development, or production operations, the amount is at least $100 million, or proof of participation in a pooled fund that is maintained at a minimum of $250 million. Operators can satisfy this part of the financial requirement through a number of mechanisms including:

- letter of credit;
- bank letter of guarantee;
- indemnity bond;
- proof of participation in a pooled fund (for offshore drilling, development, or production activities); and
- any other form that is satisfactory to the C-NLOPB.

For financial resources, the operator must provide proof that it has the financial capacity necessary to pay the absolute liability limit applicable to the work or activity. This requires the operator to provide to the C-NLOPB a Statement of Net Assets or Funding Arrangements.

Under current legislation, the C-NLOPB would be the regulator for the offshore portion of any onshore-to-offshore development in Western Newfoundland. While on-land incidents could occur (e.g., a truck with fluids going off the road or a spill at a wellhead onshore), the costs of damages are unlikely to exceed those covered by the C-NLOPB's revised financial requirements (C-NLOPB, 2016). As long as these funds are accessible to address on-land incidents, the financial security already in place for the C-NLOPB is probably adequate. Note that the financial security requirements set for the NEB for onshore activities are significantly lower than the financial security requirements for offshore activities required by the C-NLOPB or the C-NSOPB. Application of the C-NLOPB financial security requirements to cover both the onshore and offshore activities may need to be dealt with in the context of consolidating regulation under a single regulator as discussed in Section 14.5.4.

The Panel is not aware of any study that has attempted to quantify the dollar-value of damages that may result from spills, leaks, or other incidents affecting Port au Port Bay or other offshore areas in the region. Such a study should be undertaken, and it should include an assessment of the potential impact on tourism and fisheries that may result from an oil spill or from leaks.

Finally, it is important to recognize that the size of the financial requirements for offshore activities administered by the C-NLOPB will effectively limit the number of companies involved in unconventional oil and gas development in Western Newfoundland.

Panel Recommendation (PR79): Assess the Potential Impacts of Spills or Other Incidents – Undertake a thorough assessment of the potential damage that could result from spills, leaks, or other incidents in Port au Port Bay, or in any other offshore areas that may be affected by development. This should include a particular focus on impacts on tourism and fisheries.

Panel Recommendation (PR80): Require an Appropriate Security Deposit from Industry – Require an appropriate security deposit and evidence of financial capacity from the companies holding leases to ensure that there are readily available financial resources and financial capacity to deal effectively with any onshore or offshore spills, leaks, or other incidents that may occur during exploration, development, production, and abandonment of a well.

14.6 Other Scientific and Technical Considerations

14.6.1 Seismicity Risks During Hydraulic Fracturing Operations

Should unconventional oil and gas development proceed in Western Newfoundland, there will be a need for ongoing monitoring and interpretation for induced seismicity and for adapting operations in the event of seismic events. The Canadian Association of Petroleum Producers (CAPP) developed an operating practice for its members to respond to anomalous induced seismicity (AIS) from hydraulic fracturing operations (CAPP, 2012a). Appendix K of this report summarizes the CAPP operating practice (Eaton & Krebes, 2016):

1. ***"Assess the Potential for AIS.*** *This step is undertaken using available engineering, geologic and geophysical data to characterize the geological setting of the site, including pre-existing faults and historical seismicity. It also includes communication with other operators to share data and experiences, and understanding the local context including the local population and built environment.*

2. ***Design Considerations.*** *This aspect of the operating practice includes evaluation of wellbore placement to account for local surface and geological conditions, in addition to communication with onsite personnel to recognize and be prepared for the possibility of AIS. It also includes establishment of appropriate monitoring procedures and authorization of onsite personnel to suspend operations if anomalous conditions are experienced or suspected.*

3. ***Mitigation and Response Procedures.*** *This aspect of the operating practice may entail situational assessment, increased monitoring activities, temporary suspension of operations, review of available subsurface data, engineering trials to adjust operating procedures, reporting and discussion with the regulator, and sharing learnings with other area operators. If AIS escalates to site-specific threshold levels that could present harm, onsite personnel are expected to suspend operations immediately and report to the regulator. The company is then expected to consult with the regulator to establish amended procedures for restarting operations".*

In February 2015, following reports of seismic activity in December 2014 and January 2015, the Alberta Energy Regulator (AER) issued subsurface order #2, an order that specifies how operators in the Duvernay Zone have to monitor and report seismic activity (AER, 2015a). This includes a requirement for the operators to assess the potential for induced seismicity in the Duvernay Zone. Furthermore, the AER order requires that operators:

> *"Establish and be immediately prepared to implement a plan to monitor for, mitigate, and respond to induced seismicity that may occur or result from its completion operations, retain a copy of the plan on site during fracturing operations, and submit the plan to the AER upon request"* (AER, 2015a).

The AER order includes a Traffic Light Protocol (TLP), which, as discussed in Appendix K, *"is a site-specific, real-time, risk management system with multiple discrete risk levels"* (Eaton & Krebes, 2016). Furthermore, *"each TLP level is determined using observable criteria and invokes specific actions designed to mitigate risk"*. Figure 49 illustrates the TLP for hydraulic fracturing in the Duvernay Zone.

AER (2015a) requires the operators to implement seismic monitoring capability that can detect local magnitude (M_L) 2.0 seismic events within 5 km of a well. Seismic events below M_L 2.0 are not significant enough to be felt on the surface and do not require any specific action on the part of the operator. Seismic events between M_L 2.0 and M_L 4.0, corresponding to a yellow light in the TLP, must be reported immediately to the AER, and the operator *"must implement its induced seismicity plan in a manner that eliminates or reduces further seismic events caused by or resulting from hydraulic fracturing operations"* (AER, 2015a).

Seismic events greater than M_L 4.0 correspond to a red light in the TLP. Upon detection of such an event, the operator must report the event to the AER and must *"immediately cease hydraulic fracturing operations at the affected well, and return the affected well to a safe state"* (AER, 2015a).

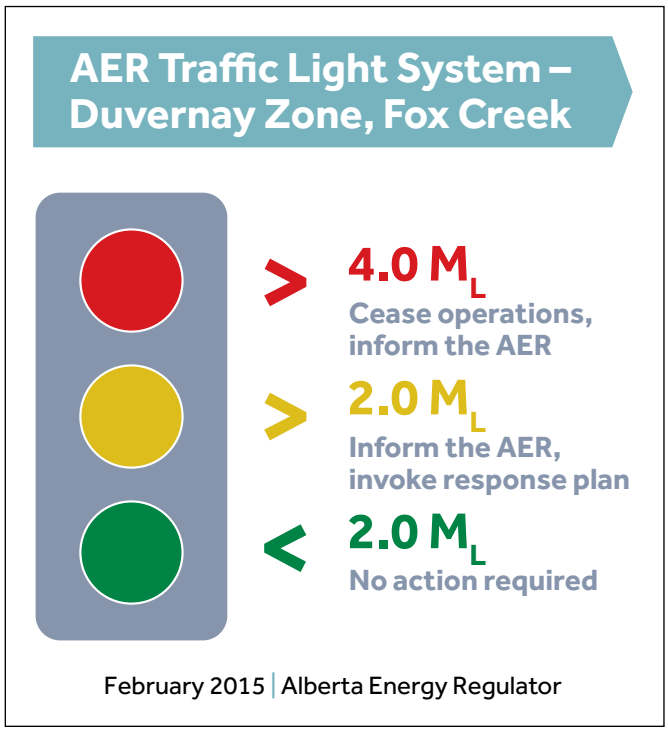

Figure 49. Alberta Energy Regulator (AER) Traffic Light Protocol (TLP) for the Duvernay Zone (AER, 2015b).

As described in Appendix K, a M_L 4.0 seismic event *"corresponds approximately to the minimum event magnitude that could result in superficial damage to built structures"* (Eaton & Krebes, 2016). The resumption of hydraulic fracturing operations that are suspended under this TLP can only be done upon receipt of written approval by the AER.

Consistent with the discussion in Appendix M, the Panel believes that best practice with respect to monitoring and management of induced seismicity is to have regulations that require a comprehensive program of microseismic monitoring, interpretation, and reporting (Lahey, 2016). This would include a clearly defined, site-specific TLP-based seismic event management system, with accountability to the regulator and disclosure to the public.

> **Panel Recommendation (PR81): Require Microseismic Monitoring –** Require the use of microseismic monitoring methods, including during initial hydraulic fracturing tests, to verify the effectiveness of operations and containment of fractures. A summary report of the monitoring results should be submitted to the regulator and released publicly.

> **Panel Recommendation (PR82): Implement a Traffic Light Protocol for Induced Seismicity Management –** Implement a Traffic Light Protocol (TLP) for induced seismicity monitoring and management. The provisions of subsurface order #2 from the Alberta Energy Regulator provides a well-documented template. Any reported seismic events should be investigated by the regulator and publicly reported.

As discussed in detail in Appendix J (Burden, 2016), Appendix H (Gagnon & Anderson, 2015), and elsewhere in this report, there are geological risks that need to be assessed to determine whether it is safe to dispose of wastewater using deep disposal wells. In the event that deep well disposal of wastewater is determined to be a practical option for Western Newfoundland, any plan to manage seismic risk arising from wastewater disposal should, as proposed in Appendix K, be based on data provided through monitoring of pore pressure in each disposal well (Eaton & Krebes, 2016).

Panel Recommendation (PR83): Implement a Seismic Risk Management Framework for Deep Well Disposal – Should deep disposal of wastewater be considered feasible, implement a seismic risk management approach that utilizes data from monitoring pore pressure in disposal wells prior to, and during, wastewater injection.

14.6.2 Well Integrity

As discussed in Section 11.4, the key to ensuring well integrity lies with the quality of the well construction, particularly the quality of the cementing process (Dusseault, 2016) (Dusseault, et al., 2014) (CCA, 2014) (Hammond, 2016). The Council of Canadian Academies Panel explains:

> *"Enough cement must be used to make sure it reaches an appropriate depth, covers the entire well casing, and displaces all the mud in the space between the casing and the borehole. In addition, the cement must be distributed over the entire length of the casing (i.e., no gaps, adequate thickness to prevent it from cracking), and it must be properly bonded to the steel casing and the rock"* (CCA, 2014).

In addition to utilizing best practices with respect to well construction, effective regulations related to well construction and response to well integrity incidents are essential. Appendix M notes:

> *"The importance of prescriptive preventative regulation on well integrity and spill prevention and containment to effective regulation of hydraulic fracturing is recognized in various reports on hydraulic fracturing and its regulation"* (Lahey, 2016).

The issue of wellbore integrity and the environmental and health impacts of a loss in integrity, however, remain topics of considerable scientific debate. As noted in Appendix D:

> *"Wellbore integrity, an issue recognized decades ago, has come under more and more expert scrutiny, with refereed scientific articles that seem, on the surface, to contradict each other, making the assessment of the environmental impact from the development of a large number of O&G [oil and gas] wells (thousands) a challenging task"* (Dusseault, 2016).

Clearly, local factors, such as the geology in the vicinity of the wellbore, are critical to assessing the risk of short-term or long-term loss of well integrity. The issue of risk of well integrity loss needs to be revisited once a more detailed development scenario has been formulated. This would include the specification of the locations of proposed wells with respect to drinking water supplies and more knowledge of the local subsurface geology and hydrogeology. This knowledge will result in a better understanding of migration pathways of any practical concern.

As recommended in Appendix M, regulations related to well integrity *"should continue to be robust and directive"* (Lahey, 2016). Appendix M also notes that for regulations related to well integrity:

> *"For risks which are not fully understood, such as the effectiveness in the longer term of the measures currently being taken and required by regulators to ensure well integrity, a precautionary approach calls for active work to improve understanding of the risk and options for reducing or mitigating it, including through research and technological development. In the meantime, it may call for additional limits on the scale or location of development or for additional safeguards against the possibility that safeguards which are currently thought adequate prove to be inadequate. It also reinforces the rationale for a comprehensive system of environmental monitoring which is designed to survive the coming and going of specific operators or companies or the industry as a whole"* (Lahey, 2016).

Improvements in regulatory practices are expected to continue. For example, a multi-level groundwater monitoring well at each multi-well drilling site, which is monitored regularly, is expected to be required by some jurisdictions Soeder (2015) notes that *"many hydrologists agree that dedicated groundwater monitoring wells located upgradient and downgradient in close proximity to a gas well site are required to properly assess the possible effects of shale gas development on groundwater levels or groundwater quality"*. Other research has identified the need for *"(1) baseline geochemical mapping (with time series sampling from a sufficient network of groundwater monitoring wells) and (2) field testing of potential mechanisms and pathways by which hydrocarbon gases, reservoir fluids, and fracturing chemicals might potentially invade and contaminate useable groundwater"* (Jackson, et al., 2013). The Panel agrees with the Canadian Water Network that:

> *"Moving beyond domestic well testing to better understand subsurface risks involves installation and sampling of monitoring wells or systems specifically designed for the purpose. Decisions should consider what is needed for sufficient baseline data and requirements for short and long-term monitoring data of active or decommissioned wells"* (CWN, 2015b).

Unfortunately, as a consequence of a lack of site access and funding, despite many thousands of wells in Canada and the United States *"only a handful of groundwater monitoring studies have been carried out to date"* (Soeder, 2015). Several approaches have been pursued to secure appropriate wells for use in field-based groundwater monitoring, including research and production wells that *"have been specifically designed for scientific research studies"* (Soeder, 2015). With such an approach to monitoring, a problem with wellbore integrity that impacts groundwater is more likely to be identified and mitigated early so as to avoid a more severe problem over a larger area. The Panel recommends that this approach be required for unconventional oil and gas development in Western Newfoundland.

Techniques for remediating leaking wells are also expected to improve and evolve. Squeeze operations involve injecting a cement slurry into cracks, gaps, or voids that have opened up in the original cement that was used when the well was completed. These operations have not been uniformly successful and cannot provide guarantees against long-term leakage (Hammond, 2016) (Dusseault, et al., 2014). In response to the limited success of using traditional cement slurries to remediate leaking wells, *"there are a number of additives and alternative sealing materials that have been developed to offer improved (deeper) penetration and better control"* (Dusseault, et al., 2014). Dusseault et al. (2014) note that *"there have also been suggestions for cement-free sealing alternatives, such as melted metals and asphalt, that claim to offer a better seal with more resilience than typical cement"*.

There has been recent success in using polymer resins to remediate leaks from cracks in cement and gaps in the cement-casing interface in a laboratory environment (Todorovic, et al., 2016). While these techniques and technologies hold promise for improving success in remediating leaking wells, the effectiveness of these approaches must be independently verified in full-scale applications. The Panel recommends that the province participate in national and international research efforts related to understanding and enhancing long-term well integrity.

Panel Recommendation (PR84): Participate in Research Activities Related to Well Integrity – Since the issue of well integrity is not limited to unconventional oil and gas wells, the province should actively participate in regional, national, and international research efforts to increase long-term well integrity through advances in well construction, monitoring, and remediation techniques and technologies.

Panel Recommendation (PR85): Require Groundwater Monitoring Wells at Each Well Pad – Require multi-level groundwater monitoring wells to be installed at each well pad by a licenced, third-party professional before any drilling of oil and gas wells is commenced. The groundwater should be independently monitored on behalf of the regulator prior to drilling of oil and gas wells and monitored annually thereafter. The monitoring results, including interpretation of the collected data, should be publicly available through the regulator.

15 CONCLUDING COMMENTS

In concluding our work, the Panel would like to leave the readers with some final thoughts. We believe that safe and responsible development of natural resources requires a combination of sound public policies; credible science; good technology; effective regulatory oversight; competent and ethical professionals working for Government, the regulator, and industry; and good will from communities and other stakeholders. These are the things that should be expected and that Newfoundland and Labrador already has experienced with its established offshore oil and gas industry. These sentiments were also reflected in the public opinion survey carried out as part of the review process.

When we began our process, the Panel was neutral with respect to its opinion about whether unconventional oil and gas development should proceed in Western Newfoundland. As we conclude our review process, based on what we have learned through the process, the Panel remains neutral with respect to an opinion since more information is required for a full and fair assessment of the development challenges and opportunities.

Our consideration of whether unconventional oil and gas development should be pursued in Western Newfoundland has identified issues that are unique to the circumstances of the region and the province. Some issues are scientific and technical, while others relate to public policy. Within the context of Western Newfoundland, if the cost and technological barriers are too high, development will not happen; if supportive public policy and regional economic development frameworks and a robust regulatory regime are not implemented, development should not be permitted; and if the science of the geological formation continues to be poorly understood, the technical risks associated with development will remain unacceptably high. Without a better scientific understanding the geological formations of commercial interest, it will not be possible to successfully address the challenges of unconventional oil and gas development in Western Newfoundland. As a consequence, the potential opportunities that could accompany developments cannot be realized for the benefit of the people of the region.

While the Green Point shale has the potential to be an economically viable source of oil and gas, we do not believe it is an energy resource that is important to meeting the current or anticipated energy needs of Newfoundland and Labrador. In this respect, the situation is different from that which exists in other jurisdictions, such as Nova Scotia and New Brunswick, where shale gas is a potential domestic source of fuel for gas-fired power generation facilities and home use.

We believe that oil from the Green Point shale represents an export commodity that could, at sufficiently high prices, return modest revenues to the province, relative to revenues from other oil exports. Through an appropriate revenue sharing model, some of these revenues could be invested within the region where development takes place. It is our opinion that unconventional oil and gas development in Western Newfoundland, if it is to proceed, must be set within forward-looking energy and climate change policies for the province and within regional economic development plans for the regions most affected by these potential developments.

We do not know whether the development of the Green Point shale represents a single project around Port au Port Bay or the start of a much larger and geographically diffuse industry in Western Newfoundland. We believe that studies, similar to those carried out by Government scientists and reported on for the Green Point shale and to those commissioned or undertaken by the Panel, would provide important knowledge and experience in support of an evaluation of the costs, benefits, risks, and scale of other potential developments.

Based on an assessment of information available through the review process, we believe that, under the right circumstances, development of the Green Point shale resource could benefit Western Newfoundland, and in particular the Stephenville-Port au Port local area, in terms of employment, business activity, and an appropriate sharing of the fiscal benefits. Also, based on what is known at this point about the prospective resources, we do not believe that development would be particularly significant to the province in terms of its economic, fiscal, or employment impacts.

Unlike other jurisdictions where unconventional oil and gas development has taken place, the geology of the Green Point formation is complicated and does not offer the well-defined layer-cake structure that is often portrayed for other developments. We feel that the complicated geology of the Green Point shale, coupled with a limited understanding the geology, underlies public concerns about health risks and damage to the environment that could result from the migration of chemicals and hydrocarbons through geological structures that are not well understood. This also gives rise to uncertainty with respect to the technical and commercial viability of development.

If unconventional oil and gas development is to take place in Western Newfoundland, we believe it is critical that appropriate scientific studies are first undertaken. This includes, but is not limited to, studies required to understand the Green Point shale. These studies will facilitate the understanding of the local geology and hydrogeology that is required to quantify the public health, environmental, socio-economic, and commercial risks and to determine whether mitigation of these risks is feasible in a specific development context. Some of the required baseline studies, for example the assessments of seismicity and coastal change, have to take place for several years prior to a development. The results of these studies will be important to consider when deciding whether to permit unconventional oil and gas development, and when specifying regulations and conditions related to development. Also, as suggested in many submissions to the Panel, a Health Impact Assessment must be carried out as part of Government's consideration whether to permit unconventional oil and gas development in a particular region.

To avoid issues that have been encountered in other jurisdictions, we believe that baseline health and environmental data must be collected in advance of development activity. Risks must be identified, assessed, and effectively managed. While we recognize that there may not always be alignment between actual and perceived risks, effective community engagement in processes related to risk assessment and risk management will be a critical part of earning and maintaining public confidence.

Monitoring programs, including interpretation of collected data, must be designed and incorporated into exploration and development plans. Data and interpretations for key environmental and public heath impact indicators must be available in the public domain. These monitoring programs must be continued throughout production and beyond well decommissioning and abandonment. A robust, comprehensive, and transparent regulatory system for unconventional oil and gas development must also be developed and implemented. Best practices must be employed by industry to minimize the occurrence of incidents and accidents that could result in negative public health impacts, worker health and safety impacts, or environmental impacts.

We believe that public confidence and trust must be treated as a priority by Government and industry. Government must gain and maintain public confidence as it considers whether it will move forward from the current "pause" in accepting applications involving hydraulic fracturing in Western Newfoundland. The public must have confidence that industry will be managed and regulated in a manner that protects the health of people and the environment and that advances the interests of the communities most affected by development. Gaining and maintaining such confidence is a shared responsibility of Government, which is responsible for the regulatory framework, and industry, which manages industrial activity and operations. If the public is to gain confidence that industry will be a good partner, early engagement by proponents of development must also be done with transparency, honesty, and integrity.

A critical early step will be for Government to provide leadership in facilitating the necessary scientific research and public education relevant to the Western Newfoundland context, including education about the scale, benefits, and risks. We feel that there is a need for a balanced-approach to public education around the socio-economic, health, and environmental costs and benefits of unconventional oil and gas development. Furthermore, issues arising from a comprehensive analysis of more detailed Western Newfoundland development scenarios must inform the education program.

Public education must not become an effort to persuade people toward a particular position, for or against development. Rather, public education must advocate for the facts about unconventional oil and gas development set within the context of Western Newfoundland. It is our view that, where decisions are to be made on scientific

or technical matters, these decisions must be science-based. The province's post-secondary education system, in partnership with other national and international institutions with expertise in issues related to unconventional oil and gas, should play an important role in public education. Also, it is important to recognize that a small minority of people or organizations hold ideological views, either for or against development. Among those, some people or groups may not be interested in science-based information that does not support their positions.

As outlined in the mandate letter to the Minister of Natural Resources from the Premier, social licence is a factor with respect to future decisions about hydraulic fracturing in Western Newfoundland. We feel that Government must develop and communicate clearly the process by which social licence will be gauged and monitored. Effective community engagement will be critical to gaining and maintaining a social licence.

In closing, we believe that the Green Point shale resource, and other oil and gas resources that may be present in Western Newfoundland, represent unconventional opportunities and challenges for industrial development and economic growth in the region. These opportunities and challenges deserve more detailed investigation and consideration than has been given to date. We appreciate the opportunity to have been involved in consideration of an important issue for the people of Western Newfoundland.

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APPENDIX A Biographies of Panel Members

Dr. Ray Gosine *(Chair)*

Following completion of an undergraduate degree in electrical engineering at Memorial University, Dr. Ray Gosine attended Cambridge University in England where he completed a doctoral degree in robotics. Subsequently, he held teaching and research positions at Cambridge University, the University of British Columbia, and Memorial University. These appointments included an NSERC (Natural Sciences and Engineering Research Council of Canada) Industrial Research Chair in Industrial Automation at the University of British Columbia and the J.I. Clark Chair of intelligent systems for operations in harsh environments at Memorial University.

Dr. Gosine is Professor and J.I. Clark Chair in the Faculty of Engineering and Applied Science at Memorial, and through his administrative responsibilities as Associate Vice-President (Research) at Memorial he is working closely with other academic leaders on the implementation of the Research Strategy Framework and other strategic research priorities for Memorial. His research is in the areas of telerobotics, machine vision, and pattern recognition for applications in the resource industries (i.e. mining, oil and gas, aquaculture and fisheries, and forestry). He was awarded the President's Award for Outstanding Research by Memorial University in recognition of his research achievements.

From August 2002 to September 2003, Dr. Gosine was the interim Associate Dean (Graduate Studies and Research) in the Faculty of Engineering and Applied Science at Memorial and became Dean of Engineering in October 2003, serving in this capacity until March 2008. In March 2008, he was appointed acting Associate Vice-President (Research) and he was appointed Associate Vice-President (Research) in May 2011. He served as Vice-President (Research) pro tempore, from October 2008 to August 2010 and from September 2014 to March 2015.

Dr. Gosine serves on the Board of Directors for the provincial Health Research Ethics Authority and was formerly the Chair of the Board of Directors of the Professional Engineers and Geoscientists of Newfoundland and Labrador. He is a Fellow of the Canadian Academy of Engineering and a Fellow of Engineers Canada in recognition of his contributions to the field of engineering and to the engineering profession. Dr. Gosine is a registered Professional Engineer (P. Eng.) in Newfoundland and Labrador.

Dr. Graham Gagnon

Dr. Graham Gagnon is a Professor in the Department of Civil and Resource Engineering at Dalhousie University. Dr. Gagnon is also the NSERC (Natural Sciences and Engineering Research Council of Canada) Industrial Research Chair in Water Quality and Treatment and the Director of the Centre for Water Resources Studies.

Dr. Gagnon's professional and research interests focus on the management of water quality and treatment for natural and engineered systems. He has taught courses on water quality, water treatment plant design and solid waste management. Throughout his career, he has worked on applied water research projects for communities in Atlantic Canada and abroad. In recognition of his technical and leadership skills, Dr. Gagnon has provided technical advice to several government agencies on matters concerning water quality and water management. He has contributed to an assessment of drinking water policy in Alberta, a review of water concerns associated with onshore oil and gas in Nova Scotia and a long-term project regarding wastewater management in Nunavut. In 2014, Dr. Gagnon was awarded the George Fuller Award from the American Water Works Association in recognition of his engineering leadership and contributions to water quality. Dr. Gagnon is a registered Professional Engineer (P. Eng.) in Newfoundland and Labrador and Nova Scotia.

Dr. Maurice Dusseault

Dr. Dusseault is a Professor of Engineering Geology in the Department of Earth and Environmental Sciences at the University of Waterloo. He carries out research into coupled problems in geomechanics, including thermal and non-thermal oil production, wellbore integrity, deep disposal technologies for solid and liquid wastes, hydraulic fracture mechanics, CO_2 sequestration in saline aquifers, shale gas and shale oil mechanics, and compressed air energy storage in salt caverns. He holds 10 patents and has co-authored two textbooks with John Franklin (former ISRM President, deceased 2012) as well as 520 full text conference and journal articles. Dr. Dusseault works with governments and industry as an advisor and professional instructor in petroleum geomechanics. He was a Society of Petroleum Engineers (SPE) Distinguished Lecturer in 2002-2003, visiting 19 countries and 28 separate SPE sections, speaking on new oil production technologies. He teaches a number of professional short courses in subjects such as production approaches, petroleum geomechanics, waste disposal, and sand control. Dr. Dusseault presented in over 20 different countries in the last 12 years.

Current projects are focused in the areas of hydraulic fracturing of naturally fractured rock masses in differential stress states; work, energy, and stress-strain responses of deep stressed rock masses (reservoirs, mines); rock-cement-casing interaction and gas seepage along oil and gas wells; THM coupling in naturally fractured rock masses; monitoring deformation in rock masses using surface and subsurface methods; and storage of energy from stochastic renewable sources as compressed air in dissolved salt caverns.

Dr. Dusseault is a registered Professional Engineer (P. Eng.) in Newfoundland and Labrador, Ontario, and Alberta.

Dr. Wade Locke

Dr. Leonard Wade Locke is a Professor of Economics at Memorial University of Newfoundland and is currently the Head of the Department of Economics. He specializes in the Newfoundland and Labrador economy, resource economics, public finance, public policy, innovation indicators, productivity, economic impact assessment, and cost-benefit analysis. He has published extensively in a variety of public policy fields. In addition, Dr. Locke has provided his professional services to all three levels of government; to foreign governments; and to national, local, regional and international businesses. He has served as an expert commentator and analyst to the local, national and international media. His research has had a major impact on public policy, particularly on the public finance of the Province of Newfoundland and Labrador and the development of its oil and gas resources.

Dr. Locke is a Past President of the Atlantic Canada Economics Association. He is an honorary lifetime member of the Atlantic Canada Economics Association, and he was awarded the President's Award for Exemplary Community Service by Memorial University. Dr. Locek serves on the Board of Governors of the Law Foundation of Newfoundland and Labrador. For the 2013 budget cycle, he served as Senior Policy Advisor to the Minister of Finance, Government of Newfoundland and Labrador. Dr. Locke also served on the Council of Canadian Academies' Expert Panel on Canadian Industry's Competitiveness in Terms of Energy Use.

Dr. Locke's holds Masters and Doctoral degrees in Economics from McMaster University and undergraduate degrees in Economics and Science (Biology) from Memorial University. He also has a certificate in Applied Petroleum Economics from Van Meurs Associates through the Centre for Management Development at Memorial University. Dr. Locke was awarded the Queen Elizabeth Diamond Jubilee Medal in 2012. He was also a Gold Medal winner in Economics at Memorial and won the Social Sciences and Humanities Research Council (SSHRC) doctoral fellowship and several university scholarships at McMaster University.

Dr. Kevin Keough

Dr. Kevin Keough received his doctoral degree from the University of Toronto in 1971. He is Past President and Chief Executive Officer of the Alberta Heritage Foundation for Medical Research and currently operates Kevin Keough Consulting Inc. Prior to his role with Alberta Heritage Foundation for Medical Research he was Chief Scientist at Health Canada. Past roles have included Vice-President (Research and International Relations), and Head of Biochemistry at Memorial University of Newfoundland where he was a professor of biochemistry in its Biochemistry and Pediatrics departments. Dr. Keough maintained an active research laboratory for over 32 years. He is currently an Adjunct Professor of Biochemistry at Memorial University. His research interests include molecular organization and function in lung surfactant and membranes, and liposomes as carriers for vaccines and drugs.

Dr. Keough is a Fellow of the Canadian Academy of Health Science, and was a member of its inaugural council, and he was a member of its predecessor organization, the Canadian Institute of Academic Medicine. Dr. Keough was a member and Deputy Chair of the Council of Science and Technology Advisors, an external national expert advisory council that provided guidance on federal science and technology issues to the cabinet of the Government of Canada. As a former Executive Member of the Medical Research Council, he was instrumental in the creation of Canadian Institutes of Health Research, and was a member of its first governing council. He was a member of an independent panel of experts advising the President of the Treasury Board of the Government of Canada on the transfer of federal laboratories to the academic and private sector. Dr. Keough was a founding member of the Board of Directors of Genome Canada, and has also been a Board Member of Genome Atlantic and Genome Alberta. He was the Canadian co-chair of the Canadian-European Union of Science and Technology Agreement. He was also a member of the Boards of Directors of the Genesis Group Inc., the Canadian Centre for Fisheries Innovation, the Canadian Centre for Marine Communications, the Centre for Cold Ocean Resources Engineering, Operation ONLINE, and the Newfoundland and Labrador Science Centre. He was a member of the University Advisory Group of Industry Canada.

Dr. Keough is a Past President of the Canadian Federation of Biological Societies, the Canadian Society of Biochemistry and Molecular and Cellular Biology and the Canadian Association of University Research Administrators. He is also the founder of NovaLipids Incorporated.

APPENDIX B Biographies of Subject Matter Experts who Prepared Commissioned Reports

Dr. Elliott Burden, a graduate of the University of Toronto and the University of Calgary, is a Professor in the Department of Earth Sciences at Memorial University of Newfoundland. Throughout his career he has been engaged in a variety of research programmes directed towards understanding regional stratigraphy, structure, sedimentology, age and thermal maturity of petroliferous strata in eastern, western and Arctic Canada and abroad. Dr. Burden is a registered Professional Geoscientist (P. Geo.) with the Professional Engineers and Geoscientists of Newfoundland and Labrador. In addition, he holds memberships in the Geological Association of Canada and the American Association of Petroleum Geologists.

Dr. David Eaton is Professor and NSERC/Chevron Chair in Microseismic System Dynamics in the Department of Geoscience at the University of Calgary. He received his B.Sc. degree from Queen's University and M.Sc. and Ph.D. degrees from the University of Calgary. He has held academic appointments at the University of Calgary and the University of Western Ontario. He is presently Co-Director of the Microseismic Industry Consortium, a novel, applied-research geophysical initiative dedicated to the advancement of research, education and technological innovations in microseismic methods and their practical applications for resource development. In addition to microseismic monitoring and induced seismicity, his current research is also focused on the lithosphere-asthenosphere boundary beneath continents.

Dr. Tahir Husain is Professor and Associate Dean (Research) in the Faculty of Engineering and Applied Science at Memorial University with 37 years' international research and consulting experience with a focus on water and environmental issues. His research is in the areas of risk assessment, environmental modeling, and technology development. He has contributed on about 250 research publications and has worked on more than 70 research projects. Prior to joining Memorial University, he was with King Fahd University of Petroleum and Minerals in Saudi Arabia. He was also a Visiting Scientist at the Harvard School of Public Health.

Dr. Faisal Khan is Professor and Vale Research Chair of Safety and Risk Engineering in the Faculty of Engineering and Applied Science at Memorial University. He is also Head of the Department of Process Engineering. His areas of research interest include offshore safety and risk engineering, asset integrity management, inherent safety, and risk-based integrity assessment and management. He advises multinational oil and gas industries and regulatory agencies on the issue of safety and asset integrity. He is a recipient of the President's Award for Outstanding Research and the President's Award for Outstanding Research Supervision at Memorial University, and the CSChE National Award on Process Safety Management. Dr. Khan has authored five books and over 270 research articles in peer reviewed journals and conferences on safety, risk, and reliability engineering. He is an editorial board member for the journal Process Safety and Environmental Protection and for the Journal of Loss Prevention in Process Industries.

Dr. Edward S. Krebes is Professor of Geophysics at the University of Calgary. He obtained a B.Sc. (Honours) in Physics from the University of Alberta, a M.Sc. in Physics from the University of British Columbia, and a Ph.D. in Geophysics from the University of Alberta. He is registered as a Professional Geophysicist (P. Geo.) with the Association of Professional Engineers and Geoscientists of Alberta. His primary research interests are in theoretical and computational seismology, and in particular, in the nature of seismic wave propagation in complex subsurface structures.

Professor William Lahey is Associate Professor in the Schulich School of Law at Dalhousie University, cross-appointed to the School of Health Administration and the College of Sustainability. His research in law and public administration has focused on regulatory policy, design, legislation and administration in the environmental, energy, natural resources and health fields. He was Clerk to Mr. Justice La Forest of the Supreme Court of Canada and has served as Nova Scotia's Deputy Minister of Labour and Environment and Assistant Deputy Minister of Health. He has written or contributed to reports on regulation of aquaculture, major energy projects, distribution of natural gas and the forestry industry, as well as a number of reports on topics in health law and regulation. He chairs the Board of Directors of EfficiencyOne, the administrator of energy efficiency programs in Nova Scotia's electricity system; and chairs or serves on several other boards of directors.

Mr. Marcel LeBreton has a Masters in Economics from the University of Moncton. He is the President of EcoTec Consultants, a consulting firm specializing in the field of economic impact studies and economic development. Over the last 33 years Mr. LeBreton has contributed to over 450 studies throughout Canada, many of which involved the assessment of economic benefits in the resource sector. Mr. LeBreton is a recognized expert in the field of economic impact studies and has spoken to international audiences in Paris, Brussels, Shanghai, the United States and Canada on topics such as model development and economic benefits assessments.

Dr. Roberto Martinez-Espiñeira is Professor of Economics at Memorial University of Newfoundland, where he teaches Econometrics and Welfare Economics. He obtained his undergraduate Economics degree at the University of Santiago de Compostela (Spain), before completing his MSc in Environmental Economics and DPhil at the Environment Department of the University of York in the United Kingdom. Prior to his academic appointment at Memorial University, he was a faculty member at St. Francis Xavier University in Nova Scotia. One of his main areas of research involves the estimation of water demand functions and the analysis of issues related to water management and pricing. Another line of his work deals with the non-market valuation of goods and services. His current projects include the estimation of non-use values of wildlife species, the valuation of the environmental benefits of Integrated Multitrophic Aquaculture, and the reduction of the risks of moose-vehicle-collisions in Newfoundland and Labrador.

Dr. Doug May is Professor in the Department of Economics and the Faculty of Business Administration at Memorial University. His current research interests are in the areas of labour market dynamics and productivity growth as well as the measurement and determinants of the various domains of well-being (quality of life) including health. Over the past several years he has worked closely with the Government of Newfoundland and Labrador overseeing the conceptual development of the Community Accounts while also involved in research efforts to measure the extent and severity of poverty, the nature of demographic changes and personal income tax reform. He has been a member of the Executive Committee and also of the editorial board of the Canadian Economics Association. Dr. May is currently a member of the National Statistics Council and the Macroeconomic Accounts Advisory Committee of Statistics Canada.

Dr. Kaaren May has an MBA from INSEAD, France, as well as a PhD in Electrical Engineering from Imperial College London. She has worked in a variety of strategy consulting, project management, business development and research and development roles over her 15-year career in the UK and Canada. She was a Consultant at the global headquarters of the international management consulting firm L.E.K. Consulting in London, where she was involved in projects for clients ranging from the Government of Botswana to large private equity firms. Awards include a Sainsbury Management Fellowship and British Commonwealth Scholarship.

Mr. Barry Rodgers has been in the oil and gas industry for over 30 years, both in the public and private sectors. A graduate of Memorial University with concentrations in Economics and Mathematics, Mr. Rodgers formed Rodgers Oil & Gas Consulting in 2010. Rodgers Oil & Gas Consulting specializes in upstream oil and gas economics analysis and fiscal systems design and evaluation. The company's objective is to support fiscal system design and implementation, project economics decision-making, negotiations, policy development, and training. As a Consultant, Mr. Rodgers has completed numerous international assignments, and served a number of international advisory roles including the Russian Ministry of Fuel and Energy, the G7 Finance Ministers, and Mexico's Department of Finance and PEMEX. Rodgers Oil & Gas Consulting is co-producer of the six-volume World Fiscal Systems for Oil & Gas (WFSOG).

Dr. Keith Storey is the Principal of Keith Storey Consulting, a socio-economic consulting company based in St. John's specializing in the social and economic impacts and management of large-scale resource projects. As a Consultant he has been involved with the socio-economic assessments of a number of offshore oil, mining, hydro and other resource projects in the Province. He received his PhD from the University of Western Ontario and was a faculty member in the Department of Geography at Memorial University for almost 40 years where he continues as Honorary Research Professor. He is also an Associate of the Leslie J. Harris Centre for Regional Policy and Development at Memorial University where he is the Director of the Population Project, an exploration of the social and economic implications of the changing demographic structure and distribution of the population of Newfoundland and Labrador.

APPENDIX C Biographies of the Reviewers of the Draft Final Report

Dr. Erik Eberhardt is Professor of Rock Mechanics and Rock Engineering, and the Director of Geological Engineering at the University of British Columbia. His research focuses on the advancement and integration of geological and geotechnical field measurements, in conjunction with state-of-the-art numerical modelling, to better understand the processes responsible for complex rock mass responses to deep mining, energy extraction, and other engineering activities. Dr. Eberhardt is a registered Professional Engineer and is a past recipient of the Canadian Geotechnical Society's John A. Franklin Award for outstanding technical contributions to the application of the principles of rock mechanics and rock engineering in civil, mining, and petroleum engineering.

Mr. Ed Foran is President of Foran Management Consulting Ltd. He holds a Bachelor of Commerce degree from Memorial University of Newfoundland and is a Certified Management Consultant providing strategic planning and advisory services to industry and government with a primary focus on the upstream petroleum industry. He is knowledgeable of conventional and unconventional petroleum resource development, regulatory regimes and emerging technology trends. He managed the Hebron Public Review Commission.

Ms. Leah Fusco is a PhD candidate in Geography at the University of Toronto. Her current research examines environmental assessment and review processes related to oil development in Newfoundland and Labrador, including community participation and opposition to project proposals. She has a B.A. in Economics/Sociology from St. Thomas University and an M.A. in sociology from Memorial University. She has been researching and working in the area of oil and energy since 2005, when she started looking at the Newfoundland and Labrador oil industry as part of her M.A.. This work examined how environmental groups have responded to offshore oil development in the province. She has worked as a research assistant on several projects related to oil development in NL and Canada. Before beginning her PhD, she also spent several years working in energy policy for the Government of Nunavut and as a Research Assistant at the Leslie Harris Centre of Regional Policy and Development at Memorial University.

Dr. Paul Gully is a Public Health Consultant and Adjunct Professor in the School of Population and Public Health, UBC. Most recently he was requested by the Public Health Agency of Canada (PHAC) to support the World Health Organization (WHO) in Geneva on emergency reform work. He has served as an advisor to the British Columbia First Nations Health Authority, and to Toronto Public Health on a health impact assessment. Dr. Gully was seconded to the WHO from PHAC, and he also worked for the WHO on the Ebola response in Sierra Leone. He was a member of the Council of Canadian Academies Expert Panel on the Effectiveness of Health Product Risk Communication. Dr. Gully was Senior Medical Advisor to the Deputy Minister of Health Canada, and he was Deputy Chief Public Health Officer for Canada in PHAC. Dr. Gully has worked in public health at the local and regional levels in Canada and the UK.

Dr. Christopher Loomis is a retired Professor of Pharmacology in the School of Pharmacy and the Faculty of Medicine, and former Vice-President (Research) of Memorial University. He served as President and Vice-Chancellor Pro Tempore of Memorial University. Dr. Loomis is a former member of many boards including the Governing Council of the Canadian Institutes of Health Research (CIHR), the Board of Directors of Canarie, and the Panel of Examiners of the Pharmacy Examining Board of Canada. He continues to serve on the Science Advisory Board of Health Canada, as well as other expert panels. Dr. Loomis is a Fellow of the Canadian Academy of Health Sciences (CAHS). His research interests are in the area of spinal pharmacology of pain.

Dr. John McLaughlin is President Emeritus of the University of New Brunswick and is currently Scholar in Residence at UNB's Centre for Technology, Management and Entrepreneurship. He is a Past President of the Canadian Academy of Engineering and a former Governor of the Council of Canadian Academies. He has an academic background in engineering and institutional economics, and has authored or co-authored more than two hundred publications, including three books published by Oxford University Press and a series of monographs published by the U.S. National Academy of Sciences. Dr. McLaughlin has worked in more than 40 countries and co-founded two companies. He is a recipient of both the Order of Canada and the Order of New Brunswick. Most recently Dr. McLaughlin served on

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Dr. Axel Meisen is a Strategic Consultant and Advisor to private- and public-sector clients, focusing on the identification and interaction of fundamental forces that shape the long-term future of organizations and communities in Canada and abroad. He held the inaugural Chair in Foresight at Alberta Innovates – Technology Futures. Dr. Meisen served as President of Memorial University of Newfoundland, and was the President of the Canadian Commission for UNESCO. Prior to coming to Memorial as President, Dr. Meisen was a Professor of Chemical Engineering at the University of British Columbia (UBC) where he was the Dean of Applied Science. He is a Fellow and former President of the Canadian Academy of Engineering. Also, he is a Fellow of the Chemical Institute of Canada, and the Institution of Engineers of Ireland. Dr. Meisen is a Professional Engineer (P.Eng.) and European Engineer (EurIng). He is a member of the Order of Canada and the Board of the Council of Canadian Academies.

Dr. Penny Moody-Corbett is Associate Dean Research and Senior Associate Dean (Thunder Bay) for the Northern Ontario School of Medicine. She was formerly the Associate Dean Research and Graduate Studies for the Faculty of Medicine at Memorial University and the Director of Ethics and the Strategy on Patient Oriented Research with the Canadian Institutes of Health Research. Her biomedical research focus is in neuroscience and more recently her work has focused on ethics and integrity issues related to the health sciences. She is the Chair of the Ethics Committee for the International Union of Physiological Sciences.

Mr. Tom Murphy is Director of the Marcellus Center of Outreach and Research (MCOR) at Penn State University. He has 30 years of experience working with public officials, researchers, industry, government agencies, and landowners during his tenure with the outreach branch of the University. His work has centered on educational consultation in natural resource development, with an emphasis specifically in natural gas exploration and related topics for the last ten years. He lectures globally on natural gas development from shale, the economics driving the process, and its broad impacts including landowner and surface issues, environmental aspects, evolving drilling technologies, critical infrastructure, workforce assessment and training, local business expansion, resource utilization, financial considerations, and LNG export trends. Mr. Murphy provides leadership to a range of Penn State's related Marcellus research activities and events. He is a graduate of Penn State University.

Dr. Andre Plourde is Professor, Department of Economics and Dean, Faculty of Public Affairs, Carleton University. He received his B.A. and M.A. in Economics from the University of New Brunswick, and a Ph.D. in Economics from the University of British Columbia. Dr. Plourde has also held academic positions at the University of Toronto, the University of Ottawa, and the University of Alberta. He served as Director of Economic Studies and Policy Analysis with the federal Department of Finance, and he also served as Associate Assistant Deputy Minister for the energy sector at Natural Resources Canada. Dr. Plourde served on Alberta's Royalty Review Panel, and he also served as President of the International Association for Energy Economics. He was a member of the Royal Society of Canada's expert panel on the environmental and health impacts of Canada's oil sands industry. Dr. Plourde's research interests are mainly on energy economics and on Canadian energy and environmental policy issues.

Dr. Donald Savoie holds the Canada Research Chair in Public Administration and Governance (Tier 1) at l'Université de Moncton. He has published widely in public administration and economic development. His work has won prizes in Canada, the United States and Europe. He was awarded the Killam Prize in Social Sciences (2015), seven honorary doctorates by Canadian universities, a D. Litt. from Oxford University and elected Visiting Fellow at All Souls College, Oxford. He was made an Officer of the Order of Canada, a member of the Order of New Brunswick and elected Fellow of the Royal Society of Canada. Dr. Savoie has served as an advisor to several federal, provincial and territorial government departments and agencies, private-sector entities, independent associations, the OECD, the World Bank, and the United Nations. At the request of the Prime Minister of Canada, Dr. Savoie undertook a review of the federal government's regional development programs in Atlantic Canada and prepared a report that led to the establishment of the Atlantic Canada Opportunities Agency.