Newfoundland & Labrador Basis for Development of Guidance Related to Hydraulic Fracturing: Part 2

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Introduction

This is the second of a trilogy of papers addressing hydraulic fracturing regulation in the context of Newfoundland & Labrador (NL). The first paper provided a high-level overview of the NL legislative framework relevant to hydraulic fracturing, and it also discussed some of the regulatory challenges and regulatory goals associated with hydraulic fracturing.

This paper will discuss a number of examples of regulatory approaches used in Canadian jurisdictions to address these regulatory challenges and meet these regulatory goals respecting hydraulic fracturing. The final paper, the most extensive of the trilogy, will provide draft Guidelines that NL may adopt to provide greater clarity to its existing legislative and regulatory framework and to ensure this framework will adequately and comprehensively ensure hydraulic fracturing operations in NL's onshore can be conducted safely, while protecting the environment and meeting resource conservation goals.

Background and Perspective in Regulatory Initiatives

The recent media attention and focus on hydraulic fracturing has resulted in a number of jurisdictions, agencies, associations and academics having conducted or being in the process of conducting reviews, studies or reports that assess the effects of this activity and recommend operating practices to ensure impacts are minimized. Regulators in other jurisdictions in Canada have also undertaken major reviews of hydraulic fracturing, and have initiated regulatory changes in response to these reviews. These regulators have taken a variety of approaches, and so far these changes have often been through creating and/or revising guidance, directives or best practices rather than changing the regulations themselves.

This paper will summarize some of the key studies, reports and best practices that have recently been developed or published by other organizations or governments and that NL could potentially follow to achieve its desired outcomes. Part Three will seek to incorporate the best of these studies, reports and best practices into a guidance document that can be used in NL to ensure environmental effects are minimized, with flexibility to allow for continuous improvement.

This discussion will start with a list of issues and activities recently published by the Petroleum Technology Alliance of Canada (PTAC) relating to hydraulic fracturing where BMPs may be adopted. Although presented as BMPs, we note that NL could choose from a variety of regulatory instruments in addition to BMPs to achieve the desired outcomes. We also review some specific BMPs that have been developed by some industry or technical organizations (namely, Canadian Association of Petroleum Producers (CAPP) and American Petroleum Institute (API)) to address aspects of hydraulic fracturing. Finally we look at some regulatory initiatives by some regulators (namely, the Alberta Energy Regulator (AER), British Columbia Oil and Gas Commission (OGC), Quebec (Développement durable, de l'Environnement, de la Faune et des Parcs) and New Brunswick (Energy and Mines)) that are dealing with hydraulic fracturing in their respective jurisdictions, with activities at varying stages and scales of development.

In addition to BMPs (although not always called such) from organizations including PTAC, CAPP, API and Enform, the high public profile of hydraulic fracturing has resulted in government organizations such as Canada's Commissioner of the Environment and Sustainable Development[1], and others, publishing reports or papers on the state and status of hydraulic fracturing in the country.

Internationally, the International Association of Oil and Gas Producers[2], Harvard Kennedy Center's Energy Technology Innovation Policy Research Group[3], the New York Governor's Marcellus Shale Advisory Commission[4], the Resources For the Future Organization[5] and the US Secretary of Energy Advisory Board[6], to name just a few, all waded into the hydraulic fracturing debate with reviews, updates and analysis on this controversial topic. The goal of all, it seems, is not to stop hydraulic fracturing, but to make it safer, more environmentally sound and more acceptable to the public.

PTAC's Recommended Areas for Adopting BMPs

A recent PTAC report[7] suggests implementing Best Management Practises (BMPs) as an effective mechanism to reduce and mitigate the risks associated with hydraulic fracturing operations. PTAC describes a BMP as "a suite of technologies, methods, and procedures that are site-specific, economically feasible, generally voluntary, and usable for guidance or help in achieving a desired outcome"[8].

The PTAC report recommends BMPs be adopted in the following areas:

- *Review of Baseline Conditions* – seek to identify potential problems that could occur during fracturing operations by carefully examining conditions surrounding the proposed well,
  - Baseline local conditions – evaluate nearby oil and gas wells to identify issues that may require mitigation before commencing hydraulic fracturing operations
  - Baseline water testing – collect baseline water samples from nearby water sources to provide the well operator, regulatory agency, and landowners with baseline water quality information
  - Baseline geologic conditions – identification of geologic hazards is integral to proper design, completion, and stimulation of a well,

[1] http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201212_05_e_37714.html#hd2b.

[2] http://www.ogp.org.uk/news/2013/april/ogp-publishes-faqs-for-hydraulic-fracturing/.

[3] http://belfercenter.ksg.harvard.edu/files/mauter-dp-2013-04-final.pdf.

[4] http://www.portal.state.pa.us/portal/server.pt/community/marcellus_shale_advisory_commission/20074.

[5] http://www.rff.org/Publications/Pages/PublicationDetails.aspx?PublicationID=22153.

[6] http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

[7] http://www.ptac.org/projects/142 (referred to hereafter as PTAC), page 57ff.

[8] PTAC. p.57.

- *Appropriate Wellbore Construction* – design and construction of the wellbore is a crucial part of mitigating the impacts associated with hydraulic fracturing,
- *Fracture Evaluation* – use of wireline tracer surveys to determine the height of fractures created during hydraulic stimulation procedures,
- *Use of Green Fracturing Chemicals* – use of chemicals formulated with non-toxic substances or designed to break down into non-toxic substances in the environment after they have performed their intended task can reduce hazards associated with surface spills and subsurface migration of fluids to groundwater resources,
- *Reduction of Chemical Usage* – closely reviewing the effectiveness and necessity of each chemical additive to decide which to use in order to reduce the overall risk of chemical usage,
- *Cement Integrity Logging* – use integrity logging methods to evaluate and confirm the cement integrity and ensure the cement has formed a competent seal between the casing and the surrounding rock to prevent the flow of fluids behind the casing,
- *Well Integrity Testing* – use of a casing pressure test, after casing is installed and cemented into place, to ensure the casing integrity is adequate to meet the hydraulic fracturing objectives planned for the well; in addition to the casing pressure test, use of a shoe test or leak-off test after drilling out the casing strings,
- *Fracturing Treatment Design* – use of site-specific data gathered during construction and logging of the well prior to stimulation to design and model the fracturing treatment to site-specific conditions,
- *Pre-Fracturing Treatment and Analysis* – use of a mini-frac test prior to initiating a full-scale hydraulic fracture treatment can provide site-specific details of the formation being treated to determine the breakdown pressure of the formation,
- *Monitoring During Hydraulic Fracturing* – real-time monitoring and control of treatment progression and fracturing geometry can identify potential problems with the hydraulic fracture stimulation and allow operators to stop them before they cause harm,
- *Post-Fracture Modeling* – use of information collected from a hydraulic fracture treatment can provide information not otherwise available to make improvements and changes in future stimulation design, and
- *Information Exchange* – information should be freely exchanged between the operators, public, and regulators when developing a resource and especially when developing in a new area, to help remove fear of the unknown and promote cooperation.

The PTAC Report focuses on identifying areas for adopting BMPs, but leaves the specifics of development of the BMPs to others. While BMPs are described as “generally voluntary”, many of the provisions and requirements of these BMPs could be incorporated in the regulations as mandatory requirements. A strictly voluntary approach to adopting BMPs may not give the public the assurance it

seeks that hydraulic fracturing is being adequately regulated. However, we believe NL can achieve the outcomes these practices are intended to achieve without necessarily having to amend its regulations.

CAPP's Recommended Operating Practices

The Canadian Association of Petroleum Producers (CAPP) has developed and adopted the following guiding principles and operating procedures in support of a responsible approach to hydraulic fracturing and water management:[9]

- *safeguard the quality and quantity of regional surface and groundwater resources through sound wellbore construction practices, sourcing fresh water alternatives where appropriate, and recycling water for reuse as much as practical.*
- *measure and disclose water use with the goal of continuing to reduce effects on the environment.*
- *support the development of fracturing fluid additives with the least environmental risks.*
- *support the disclosure of fracturing fluid additives.*
- *continue to advance, collaborate on and communicate technologies and best practices that reduce the potential environmental risks of hydraulic fracturing.*

To complement and flesh out these principles, CAPP has also established a series of Hydraulic Fracturing Operating Practices that are outlined below.[10]

#1 Fracturing Fluid Additive Disclosure

To reassure Canadians about the safe application of hydraulic fracturing technology, this practice outlines requirements for hydraulic fracturing operators to disclose, on their own websites or on a third-party website, for each well undergoing hydraulic fracturing:

- the trade name of each additive and its general purpose in the fracturing process,
- the name and the Chemical Abstracts Service number of each chemical ingredient listed on the Material Safety Data Sheet (MSDS) for each additive,
- the concentration of each reportable chemical ingredient.

#2 Fracturing Fluid Additive Risk Assessment and Management

This practice outlines requirements for risk-based assessment and management of fracturing fluid additives to allow hydraulic fracturing operators to better identify and manage the potential health and environmental risks associated with these additives, and thereby select fracturing fluids with lower risk profiles, where possible.

[9] http://www.capp.ca/getdoc.aspx?DocId=218125&DT=NTV.

[10] See http://www.capp.ca/canadaindustry/naturalgas/pages/default.aspx.

#3 Baseline Groundwater Testing

This practice outlines the requirements for hydraulic fracturing operators to test domestic water wells within 250 metres of shale gas, tight gas and tight oil development, and to participate in longer term regional groundwater monitoring programs in order to establish baseline characteristics of the groundwater predevelopment, and to analyze whether there have been changes over time.

#4 Wellbore Construction and Quality Assurance

This practice outlines the requirements for hydraulic fracturing operators to ensure all wellbores used in hydraulic fracturing operations are designed, installed and maintained to ensure wellbore integrity prior to initiating hydraulic fracturing operations thereby preventing any fluids from migrating into groundwater zones.

#5 Water Sourcing, Measurement and Reuse

This practice outlines the requirements for hydraulic fracturing operators to safeguard water quantity through assessment and measurement of available water supply sources and water use, and reusing water as much as practical in hydraulic fracturing operations.

#6 Fluid Transport, Handling, Storage and Disposal

This practice outlines the requirements for hydraulic fracturing operators to transport, handle, store and dispose of all fluids (fracturing fluids, produced water, flowback and fracturing fluid waste) in a manner that is safe and environmentally responsible by implementing practices and procedures to identify, evaluate and mitigate potential risks related to fluid transport, handling, storage and disposal, and respond quickly and effectively to an accidental spill of fluids (including remediation of the spill site).

#7 Anomalous Induced Seismicity: Assessment, Monitoring, Mitigation and Response

To reassure Canadians about the safe application of hydraulic fracturing technology, this practice outlines requirements for hydraulic fracturing operators to assess the potential for anomalous induced seismicity[11] and, where necessary, to:

- appropriately evaluate wellbore placement and drilling design to account for geologic conditions;
- communicate and prepare onsite personnel for the possibility of anomalous induced seismicity;
- establish procedures to monitor for induced seismicity; and
- establish procedures to mitigate and respond to anomalous induced seismicity.

CAPP is an industry association, not a regulator, so it cannot require its members to adopt these Operating Practices. However, CAPP strongly recommends that companies adopt these Practices. A

[11] Anomalous seismicity is **s**eismicity that would not normally occur when performing hydraulic fracture completions (such as seismicity from fault movement); induced seismicity is seismic events that can be attributed to human activity, including hydraulic fracturing. See http://www.capp.ca/getdoc.aspx?DocId=217532&DT=NTV.

regulator, such as NL's Department of Natural Resources would have the authority to require these Practices be implemented and followed.

API's Hydraulic Fracturing Practices

The American Petroleum Institute (API) is a national industry association representing all aspects of USA's oil and natural gas industry. In additional to advocacy and negotiation with governmental, legal and regulatory agencies, API has been a leader in developing equipment and operating standards for the oil and natural gas industry that are used globally. API works with leading industry subject-matter experts to maintain an inventory of over 600 standards and recommended practices. API standards are designed to assist the industry improve the efficiency and cost-effectiveness of its operations, comply with legislative and regulatory requirements, safeguard health and protect the environment. Many of API's standards, recommended practices and technical reports have been incorporated into regulations as regulatory requirements in the USA and Canada[12].

Among the API standards most commonly cited by regulators are those relating to casing and cementing, which are critically important aspects of wellbore integrity. More recently, API has developed a set of 5 documents that specifically address the risk management issues accompanying unconventional well construction and management[13]. These robust practices, outlined below, are designed to help protect the public by providing strong, carefully maintained wells.

HF1 – Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines

1st Edition, October 2009

- outlines practices for well construction and integrity for wells that will be hydraulically fractured;
- identifies actions to protect shallow groundwater aquifers, while enabling economically viable development of oil and natural gas resources.

HF2 – Water Management Associated with Hydraulic Fracturing

1st Edition, June 2010

- identifies best practices to minimize environmental and societal impacts associated with the acquisition, use, management, treatment, and disposal of water and other fluids associated with hydraulic fracturing;
- focuses primarily on issues associated with hydraulic fracturing pursued in deep shale gas development, but also describes important distinctions related to hydraulic fracturing in other applications.

[12] Not referenced in any NL regulations, but, for example, extensively referenced in C-NLOPB's *Drilling and Production Guidelines*; see http://www.cnlopb.nl.ca/pdfs/guidelines/drill_prod_guide.pdf.

[13] http://www.api.org/~/media/Files/Policy/Exploration/Hydraulic_Fracturing_InfoSheet.pdf.

HF3 – Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing

1st Edition, February 2011

- identifies best practices for minimizing surface environmental impacts associated with hydraulic fracturing operations;
- focuses on protecting surface water, soils, wildlife, other surface ecosystems, and nearby communities;
- includes API's policy on chemical disclosure which supports transparency regarding the disclosure of the chemical ingredients, in accordance with reporting requirements and formatting of reporting and public disclosure determined by the respective regulator and subject to protection of proprietary information.

Std 65 Part 2 – Isolating Potential Flow Zones During Well Construction

2nd Edition, December 2010

- provides practices to help ensure the well is designed and constructed to contain the hydrocarbons through the wellbore and isolate them from ground water aquifers, through the use of casing, cement, and mechanical barriers;
- includes guidelines on industry cementing practices designed to optimize cement placement through considerations such as laboratory-tested slurry design, honoring pore pressure/fracture gradient window, use of spacers/pre-flushes, proper density and rheological hierarchy, fluid compatibility and adequate centralization.

RP 51R – Environmental Protection for Onshore Oil and Gas Production Operations and Leases

1st Edition, July 2009

- provides environmentally sound practices for domestic onshore oil and gas production operations, including fracturing;
- applicable to all production facilities, including produced water handling facilities, beginning with the design and construction of access roads and well locations, and including reclamation, abandonment, and restoration operations;
- Annex A provides guidance to a company respecting community relations.

These documents were created to meet or exceed US federal regulatory requirements while remaining flexible enough to accommodate variations in state regulatory frameworks that occur due to fundamental differences in regional geology and other factors. While there is some overlap with CAPP's recommended operating practices, the API documents tend to be far more detailed than CAPP's and benefit from extensive cross-referencing of complementary API standards, recommended practices and technical reports.

Enform's Industry Recommended Practices

Enform is a Canadian upstream oil and gas industry association which advocates for and develops resources for the continuous improvement of the industry's safety performance.[14] Enform assists companies to achieve their safety goals by promoting shared safety practices and providing effective training, expert audit services and professional advice. Under its Drilling and Completions Committee (DACC), Enform has developed a series of technical recommended practices, which focus on cost efficiencies, technical optimization, productivity, safety and environmental performance. DACC is responsible for developing recommended technical operating practices for the upstream oil and gas industry in the areas of drilling, completions and servicing of wells.

Enform has recently published an interim Industry Recommended Practice (IRP) to respond to and complement the AER Bulletin 2012-02: *Hydraulic Fracturing: Interwellbore Communication between Energy Wells*[15].

Interim IRP Volume #24 - Fracture Stimulation: Interwellbore Communication

Mar 27, 2013[16]

- outlines methods to reduce the risk of well control events due to interwellbore communication between an offset energy well and a subject energy well as the result of fracture stimulation operations;
- adopts a risk-based approach to identify at-risk offset wells and a corresponding risk assessment to reduce the risk of well control events;
- this interim IRP will be rescinded once the final version of IRP 24 is released, and its content will be integrated into an all-encompassing IRP 24 covering fracture stimulation in its entirety.

AER Directives

The Alberta Energy Regulator (AER) is the oldest upstream oil and gas regulatory agency in Canada, originally established in 1938 as the Petroleum and Natural Gas Conservation Board, then the Energy Resources Conservation Board (ERCB), and as of June 17, 2013 the AER[17]. It also regulates the largest oil and gas industry in Canada, and has been a leader in developing regulatory frameworks for oil and gas activities.

[14] http://www.enform.ca/about/.

[15] http://www.aer.ca/documents/bulletins/Bulletin-2012-02.pdf.

[16] http://www.enform.ca/safety_resources/publications/PublicationDetails.aspx?a=29&type=irp.

[17] Although the documents referenced below will have been issued by the ERCB, we will refer to them as AER documents, and will hereinafter refer to the ERCB as the AER, its current name.

In December 2012, the AER released "*Regulating Unconventional Oil and Gas In Alberta: A Discussion Paper*"[18] which observes that "Alberta's regulatory framework needs to evolve to meet these new challenges, to provide all Albertans with assurance that the system effectively manages the risks associated with oil and gas development, to ensure efficiency in the regulatory system for industry, and to deliver the policy outcomes established by the Government of Alberta". The AER states that it intends to develop a new regulatory framework for unconventional resource development, building upon its existing regulatory framework, with the aim of:

- clearly identifying and mitigating potential risks to public safety, the environment, and the resource,
- ensuring orderly development, and
- avoiding imposing unnecessary regulatory burden on industry.

The Discussion Paper states that the new regulatory framework will be based on the following principles: it will be **risk-based**, with regulatory responses proportional to the level of risk posed by the development; and it will be **play-focused,** with regulatory solutions tailored to an entire "play" to achieve specific environmental, economic and social outcomes. It also states that to manage the effects of unconventional resource development "a play development plan will use a performance-based regulatory approach, rather than prescribing how regulatory outcomes must be achieved"[19]. The Discussion Paper does not clearly indicate whether these regulatory framework changes will be in the regulations or by means of directives.

As a complement to its Discussion Paper, the AER has a page on its website that outlines its suite of regulatory requirements to address *Mitigating Risks of Hydraulic Fracturing*.[20] Key components of this non-exhaustive list of current regulatory requirements respecting various aspects of hydraulic fracturing are summarized below.

Protecting Groundwater from Fracturing

Well casing must be cemented to protect groundwater resources by creating a cement barrier between the well, including the produced fluids within, and all adjacent groundwater sources. The AER also requires fractured wells to be properly abandoned.

- Directive 008: *Surface Casing Depth Requirements* – sets minimum surface casing depth requirements and conditions required for setting deep surface casing, with additional requirements for specific areas in the province.

[18] See http://www.aer.ca/documents/projects/URF/URF_DiscussionPaper_20121217.pdf.

[19] op.cit. page 3.

[20] See http://www.aer.ca/about-aer/spotlight-on/unconventional-regulatory-framework/mitigating-risks-of-hydraulic-fracturing.

- Directive 009: *Casing Cementing Minimum Requirements* – outlines requirements for casing cement, including methods for determining cement tops and for use of special cements such as foam and thermal cements.
- Directive 020: *Well Abandonment* – outlines the requirements and planning process for well abandonments. Groundwater protection when abandoning a well requires all non-saline groundwater intervals be covered by cement. Licensees must identify and isolate the Base of Ground Water Protection (BGWP)[21] from the hydrocarbon formations below, as well as identify and isolate all protected intervals above the BGWP.
- Directive 083: *Hydraulic Fracturing – Subsurface Integrity* – outlines requirements for managing subsurface integrity associated with hydraulic fracturing subsurface operations. It is intended to prevent the loss of well integrity, to reduce the likelihood of unintentional wellbore communication, to prevent adverse effects to non-saline aquifers and to prevent impacts to water wells.

For shallow fracturing operations, the use of toxic fracture fluids is prohibited above the BGWP to reduce the risk of contamination. Fracturing within 200 m of a water well is prohibited and fracturing pressure is regulated to reduce the potential for shallow fracturing to impact or interfere with aquifers or water wells.

- Directive 027: *Shallow Fracturing Operations - Restricted Operations* – sets out the requirements and restrictions for shallow fracturing operations, including minimum assessment requirements for fracturing operations at less than 200 m depth. Shallow fracturing is prohibited within 200 m of a water well and within 50 m vertical below the depth of that water well.

Coalbed methane (CBM) wells completed above the BGWP require applicants to offer to test water wells within a defined radius before conducting activity to establish a baseline of water quality and quantity before CBM activity occurs.

- Directive 035: *Baseline Water Well Testing Requirement for Coalbed Methane Wells Completed Above the Base of Groundwater Protection* – outlines modified well licence and recompletion requirements for CBM wells completed above the BGWP. The AER also encourages collecting data on baseline water quantity and quality for water wells near any energy development, not just CBM wells, before drilling.

Management of Fracturing Fluids

Licensees are required to submit the composition of fracturing fluids as part of the well data collection process.

[21] Base of Groundwater Protection (BGWP) refers to a depth of 15 m below the bottom of the geological formation containing the deepest non-saline aquifer. For more detailed information, see *ST-55:* Alberta's Usable Groundwater Base of Groundwater Protection Information http://www.aer.ca/documents/bulletins/Bulletin-2007-10.pdf.

- Directive 059: *Well Drilling and Completion Data Filing Requirements* – requires well licensees to file records and reports of daily operations on wells being drilled, completed, reconditioned or abandoned. The data is collected to maintain an accurate record of each well drilled in the province both for its own use and for use in performing drilling and servicing operations in a safe and efficient manner. It includes the requirement for submission and public disclosure of chemical and water use information related to hydraulic fracturing operations conducted in Alberta after Dec 31, 2012 and provision of public access to well-specific summary hydraulic fracturing information via www.fracfocus.ca.

The AER monitors and regulates water production in wells completed above the BGWP to ensure that potential crossflow between varying water qualities and production of non-saline water is properly addressed[22].

- Directive 044: *Requirements for the Surveillance, Sampling and Analysis of Water Production in Oil and Gas Wells Completed Above the Base of Groundwater Protection (BGWP)* – outlines the requirements respecting wells with completions above the BGWP that produce total water volumes equal to, or greater than, 30 m^3 per month.

The management and storage of fracturing fluids are regulated to prevent soil, groundwater, and surface water contamination and to reduce the potential for spills, thereby allowing more effective site reclamation.

- Directive 050: *Drilling Waste Management* – provides a comprehensive overview of methods for drilling waste disposal on land and information on the associated notification, approvals, sampling and toxicity assessment.

- Directive 055: *Storage Requirements for the Upstream Petroleum Industry* – outlines requirements for the storage of materials produced (including wastes) and used in the upstream petroleum industry. Primary containment devices include aboveground and underground tanks, containers, lined earthen excavations and bulk pads. It also addresses secondary containment, leak detection, spill prevention and loss control, weather protection systems as well as operating procedures, maintenance practices and inspection programs for the containment systems.

- Directive 058: *Oilfield Waste Management Requirements for the Upstream Petroleum Industry* – outlines requirements for handling, treatment and disposal of upstream oilfield waste and provides a comprehensive overview of oilfield waste characterization, classification, manifesting, tracking and management requirements.

The AER promotes waste reduction, reuse, recycling and recovery principles through a combination of requirements and site-specific approvals. Fluids that cannot be recycled or reused must be disposed into deep underground rock formations, far below groundwater sources.

[22] Non-saline water is water with total dissolved solids (TDS) content less than 4000 milligrams per litre.

- Directive 051: *Injection and Disposal Wells - Well Classifications, Completions, Logging, and Testing Requirements* – contains the requirements for classifying injection and disposal wells and sets out procedures and practices to protect the subsurface environment, including all usable groundwater and hydrocarbon-bearing zones.
- If a spill occurs, the notification requirements are in *IL 98-1: Memorandum of Understanding between Alberta Environmental Protection and the Alberta Energy and Utilities Board regarding coordination of release notification requirements and subsequent regulatory response.*

Noise

Operators must control noise emitted from sources associated with a fracturing operation, such as diesel engines and pumping equipment.

- Directive 038: *Noise Control* – outlines requirements for noise control for all operations and facilities under the jurisdiction of the AER, and includes background information and an approach to deal with noise problems.

Water Usage

The water volume needed for hydraulic fracturing depends on the characteristics of the rock and the drilling program being implemented. Companies are encouraged to use produced (saline) water when possible and to treat and reuse flowback water for future fracturing.

- A licence from Alberta Environment under the *Water Act* is required for all diversions (eg, withdrawals, storage) of non-saline water, subject to some exemptions.

Traffic and Road Usage

- Issues relating to public roads fall within the jurisdiction of the local municipality.

Whether protecting groundwater, ensuring that drilling waste is handled responsibly or restricting shallow fracturing operations, it is clear from the above that the AER currently has a number of Directives designed to ensure the safe, responsible development of all energy resources, including unconventional resources that require use of hydraulic fracturing. AER Directives are sometimes cited by other regulatory agencies, similar to API standards and recommended practices.

New Brunswick's Rules

New Brunswick is a very small producer of natural gas and oil, and has relied to date on its existing regulatory framework to regulate production of gas and oil. But its potential shale resource has garnered a very high, and often negative, public profile based on information and images of shale gas development largely derived from the eastern USA. These public concerns prompted the Government of

New Brunswick to undertake a major review of how to regulate oil and gas activities, including hydraulic fracturing, most effectively.[23]

In February 2013, the New Brunswick Government, under its "*Responsible Environmental Management of Oil and Natural Gas Activities*" initiative, published its "*Rules for Industry*"[24]. These rules are intended to govern oil and gas activity over approximately the next two years, allowing time to determine the size of the oil and gas resource base in New Brunswick, the feasibility of its extraction and appropriate future regulation of oil and gas activities in a New Brunswick context. The rules complement an *Oil and Natural Gas Act*[25] which deals primarily with exploration and producing rights, and lightly references drilling and production activities. New Brunswick intends these rules to address hydraulic fracturing and other activities.

Note that the New Brunswick rules are clearly not regulations; they are neither in the format of a regulation nor have they been enacted by the Lieutenant-Governor in Council. They are not guidelines in the way that term is normally used respecting regulatory frameworks, as they do not complement or elaborate upon existing regulatory provisions. In some ways they are analogous to AER directives, although there does not appear to be explicit legislative authority for use of directives in New Brunswick. The rules are simply a unique instrument necessary to fill a regulatory gap in New Brunswick, and we expect they will be enforced and adhered to.

The rules are generally prescriptive and generally very stringent, although not necessarily more stringent than in a jurisdiction with a well-developed regulatory framework such as Alberta. The intent is to set a high standard, especially for hydraulic fracturing, to ensure the public interest is being protected and is seen to be protected. The discussion below outlines the components of the Rules for Industry, with each component starting with a general goal statement followed by a series of prescriptive requirements to be followed in meeting this goal.

Addressing Potential Concerns Associated With Geophysical (Seismic) Testing

These rules complement New Brunswick's *Geophysical Exploration Regulation*[26], and include measures to reduce risks to public safety, private property and the environment during seismic testing and prescribe specific technical requirements. They also respond to public concerns that have arisen in New Brunswick that seismic activity may be affecting groundwater resources.

[23] http://www2.gnb.ca/content/gnb/en/corporate/promo/natural_gas_from_shale.html.

[24] http://www2.gnb.ca/content/dam/gnb/Corporate/pdf/ShaleGas/en/RulesforIndustry.pdf.

[25] http://laws.gnb.ca/en/showfulldoc/cs/O-2.1//.

[26] http://laws.gnb.ca/en/ShowTdm/cr/86-191//.

Preventing Potential Contaminants from Escaping the Wellbore

This component of the rules primarily focuses on well casing and cementing, based on the importance of well integrity as the most effective means of reducing the potential for unintentional releases of substances such as fracturing fluids, drilling fluids, flowback water, produced water and natural gas from the horizontal or vertical segments of oil and gas wells. The rules rely extensively on references to external standards and specifications from respected regulators such as the AER or from highly specialized technical sources such as the API, International Standards Organization (ISO), Canadian Standards Association (CSA), National Association of Corrosion Engineers (NACE) and American Society of Mechanical Engineers (ASME).

Casing for wells in some geological basins, geologic formations or geographic regions, as identified by the regulator, must be designed to provide both primary and secondary barrier protection during hydraulic fracture stimulation operations through the use of a combination of intermediate casing, production casing, production liner, tubing and/or tie-back string. The secondary barrier must provide:

- protection in the event of a primary barrier (ie, the casing/tubing used to transport the fracturing fluids into the formation under pressure) failure during hydraulic fracture stimulation operations, and
- well control and an ability to repair or replace the primary barrier if the primary barrier fails.

Assessing Geological Containment Outside the Wellbore

The goal for this component is “Reducing the potential for substances such as fracturing fluids, drilling fluids, and hydrocarbons to reach water wells or the surface via underground fractures, faults, abandoned oil or gas wells, or a confining layer that is otherwise inadequate”.

Hydraulic fracturing is prohibited:

- where the target zone is less than 600 m below the surface (true vertical depth) or another depth defined by the regulator based on site-specific geology, and
- within geologic formations containing non-saline groundwater.

Managing Wastes and Preventing Potential Contaminants from Escaping the Well Pad

Means of reducing escape of substances at the surface due to spills, leaks, improper storage and handling of chemicals, and inadequate treatment or disposal of wastes such as flowback water and produced water include:

- well pad design and construction,
- closed loop, pitless systems for the management of drilling fluid,
- waste management planning , storage and disposal,
- chemicals management and transportation,
- storage tanks, vessels and containers (use of pits for the storage of flowback water or produced water is prohibited), plus
- enhanced precautions for sour gas.

Monitoring to Protect Water Quality

Monitoring groundwater and surface water is required to verify that the water-related safeguards included in the rules are effective and to provide early warning of any problems. Testing is required of all water wells within 200 m of a seismic source point and within 500 m of the well pad of an oil or gas well before drilling begins.

Providing for the Sustainable Use of Water

Measures are required to reduce freshwater consumption, to conserve potable water, and to ensure the sustainable use of water in oil and natural gas activities. A water management plan is required that addresses water conservation and recycling, and the sourcing of water based on a prescribed hierarchy of preferred water sources.

Addressing Air Emissions Including Greenhouse Gases

The rules also address emission limits, identifying emission sources, predicting, modeling and monitoring emissions and planning for emission reductions. Each operator must have a greenhouse gas reduction plan, and must consider alternatives to diesel fuel for drilling rig compressors (eg, electricity, natural gas) at locations where these alternatives are available.

Addressing Public Safety and Emergency Planning

Planning for public safety and emergency response must include an emergency management program compliant with CSA Standard Z-1600, *Emergency Management and Business Continuity Programs* and a security management program compliant with CSA Standard Z-246, *Security Management for Petroleum and Natural Gas Industry Systems.*

Protecting Communities and the Environment

Rules that address the challenges that oil and gas activities may represent for social and physical environments include:

- vehicular traffic – load sizes and weights, haul route planning, road use agreements and road system integrity studies, noise limits, mitigation and monitoring,
- facility siting – restrictions and set-backs, visual impact, protecting flood prone areas, wetlands, watercourses and communal and private water supplies, site restoration and site remediation standards, and
- addressing induced seismicity.

Reducing Financial Risks and Protecting Landowner Rights

Financial risks that may result from oil and gas activities must be addressed to protect the rights of private landowners. Oil and natural gas operators must provide financial security to protect property owners from the financial impacts of industrial accidents or damage to a water supply.

Sharing Information

An important goal is ensuring that regulators, industry and the public have access to a common set of accurate information about oil and gas activities in New Brunswick.

British Columbia Initiatives

British Columbia has a modern, results-based legislative and regulatory framework for oil and gas activities. It is also the province with the largest shale gas resource in Canada and hydraulic fracturing is already being used extensively. BC was the first jurisdiction in Canada to mandate public disclosure of chemicals used in hydraulic fracturing. Fracture Fluid Reports must be submitted to the Oil & Gas Commission (OGC) within 30 days of finishing completion operations at a well and the report will be posted to www.fracfocus.ca by the OGC immediately upon receipt. The OGC initiated this requirement by announcing it through an Information Bulletin[27] and making it part of industry's reporting requirements as authorized by regulation[28].

As in other jurisdictions in Canada, the term hydraulic fracturing is not directly used in BC's regulatory legislation. To complement its regulatory legislation, BC has issued a series of supplementary regulatory instruments that directly address various aspects of hydraulic fracturing, as follows:

- Safety Advisory 2010 – 03 – Communication During Fracturing Stimulation[29]
- Consultation and Notification Manual – February 2013[30]
- IL # OGC 09-07 – Storage of Fluid Returns from Hydraulic Fracturing Operations[31]
- Oil and Gas Water Use in BC – August 2010[32]
- Well Completion, Maintenance and Abandonment Guideline – Updated to April 2013[33]
- Well Drilling Guideline – August 2012[34]
- Well Permit Application Guideline – April 2013[35]
- Liability Management Rating Program – September, 2011[36].

[27] http://www.bcogc.ca/publications/information-bulletins/2011.

[28] Alberta also requires reporting of all fracture fluids and the posting of this information on http://www.fracfocus.ca/. Disclosure of fracture fluids is one of CAPP's best management practices respecting hydraulic fracturing.

[29] http://www.bcogc.ca/publications/safety-advisories/2010.

[30] http://www.bcogc.ca/content/consultation-and-notification-manual.

[31] http://www.bcogc.ca/publications/information-letters/2009?page=1.

[32] http://www.bcogc.ca/content/oil-and-gas-water-use-bc.

[33] http://www.bcogc.ca/well-completion-maintenance-and-abandonment-guideline.

[34] http://www.bcogc.ca/content/well-drilling-guideline.

[35] http://www.bcogc.ca/well-permit-application-manual.

[36] http://www.bcogc.ca/content/liability-management-rating-program-manual.

Quebec Initiatives

Quebec generally appears reluctant to allow oil and gas development in the province. The province is proud of its generation and use of clean energy through hydroelectricity and also has a strong commitment to the use of alternative energy generation and "green" technologies. In May 2013, the Minister of Développement durable, de l'Environnement, de la Faune et des Parcs announced a prohibition on shale gas exploration and extraction that imposes a moratorium on exploration for shale gas in the St. Lawrence River Valley for the next five years or until new regulations on shale gas exploration are in place.

However, in June 2013 the Minister announced the approval of exploratory drilling for shale oil on Anticosti Island. This approval of exploration indicates the government may be willing to allow the development of Quebec's oil and gas, if the exploration is successful, despite pressure by ecologists and other like-minded Quebecers to leave the land alone.

Behind the scenes, Quebec appears to have been closely studying hydraulic fracturing and in February 2011, the Bureau d'Audiences Publiques sur l'Environnement published a thorough, well considered document "*Sustainable Development of the Shale Gas Industry in Québec*" whose conclusions includes the following:

> "*To meet the need for more scientific knowledge and in the absence of proven facts that can be used to identify the potential risks associated with shale gas exploration and extraction, the inquiry commission has proposed a strategic environmental assessment. While the assessment is in progress,* ***hydraulic fracturing will be authorized only for work related directly to the assessment.*** *Exploration work would continue in the meantime, but without the use of hydraulic fracturing. An assessment such as this is a necessary element of both an informed decision and improved social acceptability*".[37]

It remains to be seen whether Quebec may yet permit the use of hydraulic fracturing to monetize its own oil and gas resources following this strategic environment al assessment.

NEB Filing Requirements for Hydraulic Fracturing

In September 2013, the NEB released its *Filing Requirements for Onshore Drilling Operations Involving Hydraulic Fracturing*[38]. These Filing Requirements outline the information required as part of the application process for drilling that involves hydraulic fracturing. The Filing Requirements focus on the unique aspects of hydraulic fracturing and apply only to onshore hydraulic fracturing operations in the Northwest Territories and Nunavut. Some of the information required by the Filing Requirements must be included with an application for an

[37] http://www.bape.gouv.qc.ca/sections/rapports/publications/bape273_excerpts.pdf, Page 245.

[38] http://www.neb-one.gc.ca/clf-nsi/rthnb/nrthffshr/pblctnrprt/flngrqrmntnshrdrllnghdrlcfrctrng/flngrqrmntnshrdrllnghdrlcfrctrng-eng.html.

Operations Authorization (OA), and some information must be submitted with a subsequent application for a Well Approval or Formation Flow Test Approval. The goal-oriented nature of the NEB's *Drilling and Production Regulations* results in the information required for each type of application being set out in a series of goals to be achieved, with each goal followed by detailed and comprehensive information requirements designed to demonstrate how that goal will be met. Some of the key information required by the NEB's Filing Requirements is briefly summarized below.

The NEB does not issue an OA until an environmental assessment (EA) has been conducted, either by the NEB or by the responsible northern board or agency. The NEB considers the results of the EA or the recommendations made by the respective northern board or agency before it decides whether and on what terms and conditions the proposed work or activities should proceed, including mitigative measures.

The following information is to be included in a project description, and is more fully described in the guidelines provided by the respective agency requiring or conducting the EA:

- potential impacts to the environment, including potential impacts from accidents and malfunctions;
- consultation with Aboriginal groups and the public;
- socio-economic impacts arising from environmental impacts; and
- mitigation measures to protect the environment.

The Filing Requirements outline goals and information requirements relating to the OA application that address the following aspects of the project:

- proof of financial responsibility,
- declaration by applicant or by owner,
- management system,
- management system implementation,
- safety culture,
- human factors,
- lessons learned,
- safety plan,
- risk assessment,
- environmental protection plan,
- waste management, and
- spill contingency plan.

Because of the goal-oriented nature of the NEB's *Drilling and Production Regulations*, instead of prescribing detailed and specific programs, the Filing Requirements require an applicant, among other things, to:

- Provide a water quality assurance plan for how surface water and groundwater quality will be assessed, protected and monitored for impacts from planned and unauthorized discharges from drilling, hydraulic fracturing, flaring, and formation flow testing, well suspension and abandonment and production activities;
- Provide an air quality assurance plan that describes how air quality will be assessed, protected and monitored for impacts from planned discharges and fugitive or other unauthorized discharges from drilling, hydraulic fracturing, flaring, formation flow testing, storage of produced fluids including formation and flowback fluids, well suspension and abandonment and production activities; and

- Describe how the groundwater monitoring and sampling program will detect any contamination from oil and gas operations including hydraulic fracturing operations.

An operator with an OA must obtain a Well Approval to drill, re-enter, workover, complete, recomplete, suspend, or abandon a well; this requirement applies to hydraulic fracturing, which is a well completion operation. Well approval information Filing Requirements include:

- a detailed drilling schedule, including approximate durations of hydraulic fracturing and formation flow testing;
- a geophysical assessment that identifies drilling hazards and describes the mitigative and preventive measures to be used to manage these risks during drilling and hydraulic fracturing;
- a groundwater protection program that describes
  - the process to identify groundwater zones,
  - possible groundwater contamination pathways from drilling and hydraulic fracturing operations, and
  - measures to prevent this contamination;
- a well casing and cementing program designed to
  - isolate groundwater zones from potential oil, gas and/or saline water zones,
  - provide wellbore integrity particularly in the casing annuli, and
  - be set below all known or reasonably estimated utilizable groundwater zones;
- a description of well integrity programs, including
  - how cement bond logs will be used to evaluate well control barriers to address the anticipated formation pressure and hydraulic fracturing pressure,
  - the casing pressure testing process and the criteria for successful pressure testing, and
  - quality control and testing procedures for the casing and casing accessories;
  - the testing method and procedure for monitoring each well barrier during and after the hydraulic fracturing operations,
  - the proposed well control systems for well operations, including during hydraulic fracturing and formation flow testing, and
  - the monitoring program during well completion operations, particularly monitoring pressure in the casing annuli during the hydraulic fracturing operations;
- a description of the hydraulic fracturing program design and operation, including
  - the policies, procedures, and methods for modeling the hydraulic fracturing program, including the design variables that are critical to fracture propagation,
  - the policies and procedures to maintain threshold pressure limit during hydraulic fracturing operations,
  - the basis for the selection of the fracturing fluids and chemical additives for the proposed hydraulic fracturing program,
  - the handling, treatment, disposal and waste management capabilities for the fracture fluids, flowback fluids and other used or un-used chemicals,
  - the proposed program to address any risks for inter-wellbore communication of the nearby wells, and
  - plans for monitoring of and notifying owners of suspended and abandoned offset wells affected by a proposed hydraulic fracturing operation;
- a description of the proposed all-season well pad design, including

- how the design of the well pads would safely accommodate oil and gas operations, including concurrent operations and emergency egress, and would minimize impacts to the environment, including wetlands,
- the rationale for the set-back distances of the well pad from any surface features and/or infrastructure, and
- the rationale for the proposed subsurface inter-well distances of wells located on multi-well pads as it relates to the optimizing the fracture network and the optimal recovery of hydrocarbons.

Because of the goal-oriented nature of the NEB regulatory regime, these Filing Requirements do not make any numerical references to setbacks or minimum distances. They leave it up to the operator to propose appropriate setbacks and then to demonstrate that the proposed design and operational distances are safe and will protect the environment. Also, these Filing Requirements do not refer to the Canadian “fracfocus” website nor do they allow a single barrier casing system as is done in the AER Directive 083 and is proposed in the draft NL Guidelines.

Acronyms and Definitions

Acronyms

AER – Alberta Energy Regulator

ALARP – as low as reasonably practicable

API – American Petroleum Institute

CAPP -- Canadian Association of Petroleum Producers

CAS – Chemical Abstracts Service

C-NLOPB – Canada-Newfoundland & Labrador Offshore Petroleum Board

COGOA – *Canada Oil and Gas Operations Act*

BC OGC – British Columbia Oil and Gas Commission

BGWP – base of groundwater protection

Department – Newfoundland & Labrador Department of Natural Resources

Director – the officer responsible for the administration of the *Drilling Regulations*, as designated by the Minister, and normally the Assistant Deputy Minister, Petroleum Development, NL Department of Natural Resources

EA – an environmental assessment, specifically for an authorization under COGOA

EPA – US Environmental Protection Agency

Enform – The safety association for the upstream oil and gas industry in British Columbia, Alberta and Saskatchewan

ERP – emergency response plan

FPZ – fracture planning zone

GHG – greenhouse gases

HDPE – high density polyethylene

IRP – industry recommended practice

mg/L – milligrams per litre

MSDS – Material Safety Data Sheet

NEB – National Energy Board

NL – Newfoundland & Labrador

NORM – naturally occurring radioactive materials

OA – operations authorization, under COGOA

TDS – total dissolved solids

TVD – total vertical depth

UL – Underwriters' Laboratory

Definitions[39]

Additive: Any substance or combination of substances comprised of chemical ingredients found in a hydraulic fracturing fluid, including a propping agent, which is added to a base fluid in the context of a hydraulic fracturing treatment. Each additive performs a certain function and is selected depending on the properties required.

Annulus: The space between the wellbore and casing, or between casing and tubing, where fluid can flow.

Anomalous seismicity: Seismicity that would not normally occur when performing hydraulic fracture completions (such as seismicity from fault movement).

At-risk offset well: An offset well that may be adversely affected by a hydraulic fracturing operation.

Barrier: Individual components that collectively make up a barrier system.

Base of groundwater protection (BGWP): A modelled depth at which saline groundwater is likely to occur. It is calculated as the base of the deepest protected (non-saline groundwater-bearing) formation plus a 15 m buffer.

Bedrock: Consolidated rock underlying unconsolidated glacial or drift material.

Base fluid: The base fluid type, such as water or nitrogen foam, used in a particular hydraulic fracturing treatment. Water includes fresh water, brackish or saline water, recycled water or produced water.

Casing string: An assembled length of steel pipe configured to suit a specific wellbore. The sections of pipe are connected and lowered into a wellbore, then cemented in place.

Cement evaluation log: A representation of the integrity of the cement job, especially whether the cement is adhering solidly to the outside of the casing.

Cement job: The application of a liquid slurry of cement and water to various points inside or outside the casing.

Chemical Abstracts Service (CAS): The chemical registry that is the authoritative collection of disclosed chemical substance information.

[39] Based on CAPP's Hydraulic Fracturing Recommended Operating Practices – Definitions Sections.

Chemical Abstracts Service registry number (CAS number): The unique identification number assigned by the Chemical Abstracts Service to a chemical constituent.

Chemical ingredient: A discrete chemical constituent with its own specific name or identity, such as a CAS number, that is contained in an additive.

Domestic water well: An opening in the ground, whether drilled or altered from its natural state, for the production of groundwater used for drinking, cooking, washing, yard or livestock use.

Dual-barrier system: A well system designed for hydraulic fracturing operations made up of both primary and secondary barrier systems.

Energizing gas: A gas used to improve the effectiveness of the hydraulic fracture.

Flowback: The flow of fracturing fluid back to the wellbore after treatment is completed.

Fracturing fluid: The fluid used to perform a particular hydraulic fracturing treatment and includes the applicable base fluid and all additives.

Fracture Fluid System: The fluid delivered down-hole that consists of one or more additives plus the base fluid and proppant.

Fracturing fluid waste: An unwanted substance or mixture of substances that results from the hydraulic fracturing operation, not including flowback.

Fracture planning zone (FPZ): An area that may be impacted by hydraulic fracturing operations.

High vapour pressure hydrocarbon: Any hydrocarbon and stabilized hydrocarbon mixture with a Reid vapour pressure greater than 14 kilopascals.

Free natural gas: Free gas is defined as gas that readily comes out of solution at atmospheric pressure and ambient temperature.

Fresh (non-saline) groundwater: Groundwater that has a total dissolved solids (TDS) content less than or equal to 4,000 mg/L or as defined by the jurisdiction.

Hydraulic Fracturing: A controlled operation that pumps a fracturing fluid and a propping agent through the wellbore to the target geological formation at high pressure in multiple intervals or stages, in order to create fractures in the formation and facilitate production of hydrocarbons.

Hydraulic Fracturing Program: A program comprised of one or more fracturing stages within the same wellbore.

Gas migration: A flow of gas that is detectable at surface outside of the outermost casing string. It refers to all possible routes for annular gas entry and propagation through and around the cement sheath.

Induced seismicity: Seismic events that can be attributed to human activity. Seismicity can be induced by geothermal energy extraction, mining, dam building and hydraulic fracturing.

Ingredient: The individual chemical constituents of an additive.

Material Safety Data Sheet (MSDS): A document, as required by the *Controlled Products Regulations* under the federal *Hazardous Products Act*, that contains information on the potential hazards (health, fire, reactivity and environmental) of an additive and its components.

Non-saline aquifer: An aquifer above the BGWP that contains water with a total dissolved solids content of less than or equal to 4000 milligrams per litre.

Primary barrier system: A well system designed to contain and isolate fracture fluids within the well.

Produced water: Water naturally present in the reservoir or injected into the reservoir to enhance production, produced as a co-product when gas or oil is produced.

Propping agent (Proppant): Typically non-compressible material, most commonly sand, added to the fracturing fluid and pumped into the open fractures to keep them propped them open once the fracturing pressures are removed.

Offset well: Any well that is within the FPZ of a subject well, excluding water wells.

Operator: An Operator as defined in the *Drilling Regulations*, meaning an individual or company that seeks or has been granted approval to conduct a drilling program.

Recycle: The process of treating flowback or produced water to allow it to be reused either for hydraulic fracturing or for another purpose.

Reuse: The process of using water multiple times for similar purposes.

Risk: the probability that a hazard may occur.

Risk Assessment: An assessment that:

- considers the physical, chemical and toxicological properties of the ingredients of a fracture fluid system;
- categorizes the additives (based on their ingredients) in terms of their potential health and environmental impacts;
- identifies those additives for which special controls or practices are required in order to reduce risk to human health and the environment; and
- identifies the measures proposed above.

Saline groundwater: Groundwater that has a total dissolved solids (TDS) content more than 4,000 mg/L [or as defined by the jurisdiction].

Secondary barrier system: The backup well system that provides well control in the event of a failure of the primary barrier system.

Seismicity: The frequency and magnitude of earthquake activity in a given area.

Single-barrier system: A well system designed for hydraulic fracturing operations comprised of a primary barrier system only.

Shale gas, tight gas and tight oil: For the purposes of these Guidelines, shale gas, tight gas and tight oil refers to unconventional resources from low permeability reservoirs being developed using horizontal wells with multi-stage hydraulic fracturing.

Surface casing vent flow: The flow of gas and/or liquid or any combination out of the surface casing/casing annulus.

Surface water: Water collecting on the ground or in a stream, river, lake, sea or ocean, as opposed to groundwater.

Trade name: The name under which an additive is sold or marketed.

Trade secret: Any confidential formula, pattern, process, device, information, or compilation of information entitled to protection as a trade secret under the applicable law which is used in a business and which gives the business an opportunity to obtain an advantage over competitors that do not know or use it.

Wastewater: Spent or used water with dissolved or suspended solids, discharged from homes, commercial establishments, farms and industries.

Water deliverability test: A field test to estimate the flow capacity of the water well under existing conditions (eg, using the well owner's pump). Water is withdrawn from the well for a fixed duration (usually 1 hour) before the pump is turned off and the water level is allowed to recover.

Water well: A well with the primary purpose of non-saline groundwater production.

Well control event: A flow of wellbore fluids in the subsurface from one formation to another formation, a flow of wellbore fluids at surface that can be controlled by existing wellhead or blowout prevention equipment, or a blowout.

Well integrity Prevention of the escape of fluids (ie, liquids or gases) to subsurface formations or surface.

Wellbore: For the purposes of this practice, a wellbore is defined as the open hole that is drilled prior to the installation of casing and cement.