Report to the
Minister of Natural Resources

National Energy Board | Office national de l'énergie

Canada

Best Available Technologies
in Federally-Regulated Pipelines

30 September 2016

A report by the
National Energy Board

Table of Contents

EXECUTIVE SUMMARY

Background

On 5 February 2015, the Minister of Natural Resources requested the National Energy Board (NEB) produce a report on Best Available Technologies (BAT) used in federally-regulated pipelines. The original request from the Minister included a focus on pipeline materials, construction, emergency management and emerging technology. In the spring of 2016, following the election of a new government a few months earlier, the new Minister updated the request to include a focus on environmental considerations.

Purpose of This Report

This report gathers information about Best Available Technologies (BAT) and emerging technologies in the pipeline industry, including best practices and tools. It relies on expert information from industry, academia, other governments, and the National Energy Board (NEB) and is intended as a general reference. The goal of the report is to better inform the Minister of Natural Resources about current pipeline technology, particularly relating to questions of safety and the environment.

A Snapshot

This report provides a snapshot of BAT and emerging technology, as research and development continues to drive advances that are important to increased pipeline safety. However, technological advances alone do not ensure the integrity of pipelines and pipeline facilities or the safety of people and the environment. The most important factor in any technology is how it is put into use. It is clear that technological, human, and organizational factors *combine* to determine outcomes, and these factors have to be considered in every aspect of pipeline functioning.

The report provides an overview of BAT and emerging technologies in federally-regulated pipelines. The BAT and emerging technologies included in this report are not exhaustive. Research and consultation were performed to identify the included content; however, since technology is a rapidly advancing field, this document is only a snapshot of BAT and emerging technologies in the year it was written. Future audiences should interpret its contents in this context and understand that the included content is not exhaustive.

The Role of the NEB

The NEB:

- is committed to adapting to emerging technology and scientific advancements and continues to strive toward regulatory excellence in everything it does;
- regulates pipelines, energy development and trade within the mandate set by Parliament; and
- reports to Parliament through the Minister of Natural Resources.

Consistent with our mandate, this report considers engineering and environmental protection matters related to pipelines that are regulated by the *National Energy Board Act* (*NEB Act)* and the *National Energy Board Damage Preventions Regulations – Authorizations* (*NEB DPR*).

The Structure of This Report

This report reviews best available and emerging technologies at each stage of a pipeline's lifecycle. Each chapter represents a stage in the lifecycle: 1) design, 2) pipe manufacturing, 3) pre-construction planning and construction, 4) commissioning, 5) operation, 6) deactivation and **abandonment***. This structure allows holistic coverage of BAT and emerging technologies and related engineering and environmental issues.

The design stage of the lifecycle includes steps to ensure the physical pipeline structure, route, and locations of associated facilities are best chosen to ensure the safety of people and the environment. Front end engineering design practices, risk assessments, structural and strength analyses, and choice of materials are a few of the engineering considerations in the design stage. In order to ensure pipeline construction and operation maintain environmental safety, environmental assessments are conducted that consider how to best mitigate environmental impacts during the lifecycle of the pipeline, particularly with respect to species at risk and sensitive environmental features. Environmental considerations of the design stage also include route selection and facility siting, minimizing the project footprint and equipment choices that aid in achieving this goal.

Pipe manufacturing considers pipe types, coatings, and storage techniques that contribute to the integrity of the pipeline, and consequently, the safety of people and the environment.

The pre-construction and construction phases of the pipeline system are particularly important with respect to taking preventative measures to ensure the mitigation of environmental impacts. Engineering considerations include how the pipeline route is constructed (e.g., pipe storage and transportation, digging the trench for buried pipelines, bending the pipe, lowering the pipe into the trench, welding the pipe together, inspecting the pipe to ensure the integrity was not compromised during installation, and alternate methods of drilling to avoid sensitive features like waterbodies). The variety of steps necessary to ensure mitigation of environmental impacts is also described (e.g., eco-friendly materials, noise and light pollution mitigation, construction timing and mitigation for restricted activity periods, soil management and watercourse crossings management, invasive species management, protection of indigenous traditional use of lands and resources, reducing greenhouse gas emissions, and reclamation procedures).

Commissioning of the pipeline takes place after construction. This phase of the lifecycle includes the final detailed testing and inspection of the pipe integrity necessary to demonstrate that the pipe is suitable for operation (e.g., hydro testing followed by cleaning and drying the pipe and baseline inline inspection).

The engineering and environmental considerations in the operations phase of the pipeline lifecycle have some overlap with the construction phase; however, the longer-term effects of operating a pipeline or facility may require a different combination of BAT than the temporary

* **Bolded** words in the body text of this report are defined in the Glossary section.

impacts of construction. Engineering considerations in the operations stage primarily focus on inspection of the pipeline integrity. Environmental considerations include monitoring of environmental features, reducing noise and light pollution during routine activities, erosion and sediment control, mitigation of subsidence, line patrol, rare species conservation, air emissions management, and mitigating and responding to contaminants in soil and water. Emergency management can be an area of particular importance during the operation stage and includes clean up response, reclamation and remediation, and materials disposal.

The final stage of the pipeline lifecycle is decommissioning or abandonment. This stage is associated with engineering and environmental considerations that ensure the safe decommissioning or abandonment of a pipeline. A company must adequately assess the potential land and environmental impacts in deciding whether to remove the pipeline completely, remove the pipeline partially, or abandon the pipeline in place.

Who Contributed Information to This Report

The NEB conducted two external engagement phases with industry members and associations, government agencies, and academia.[*] These bodies provided information on BAT and emerging technologies, technological uptake, and opinion on the role of regulators and industry in informing industry about BAT.

When asked about engineering considerations, respondents focused on protection from leaks.

Key **environmental considerations** that were noted by respondents include:

- leak prevention and response;
- design and pre-construction planning techniques to mitigate environmental impacts;
- impact on water bodies and agricultural land;
- waste management and pipeline **abandonment**; and
- air emissions management.

Respondents described the most effective technologies related to each of these points. Their responses and NEB research shaped each section in this report.

[*] 35 survey one respondents; 43 survey two respondents.

1.0 INTRODUCTION

1.1 Terms of Reference

On 5 February 2015, the Minister of Natural Resources requested that the Chair of the NEB study and provide a report on the use of BAT in federally-regulated pipelines (see Appendix A). This request followed an initiative announced by the Minister in May 2014. The content of the report was to include technology used in construction methods, materials, and emergency response techniques. On 19 April 2016, the Minister asked the NEB to include environmental considerations in the scope of the report (see Appendix B).

1.2 Purpose and Scope

1.2.1 Purpose of the Report

The purpose of this report is to inform the Minister of the best available and emerging technology that can be applied to planning, construction, operation, and abandonment on federally-regulated pipelines, including best practices and tools. The report presents these technologies within the framework of the life cycle of a typical pipeline, and places particular emphasis on safety to Canadians and protection of the environment. However, the breadth of scope with respect to application of technology to pipelines and the accelerated appearance of new and emerging technologies means that this report cannot be fully informed on global efforts in this area. Rather, the report focuses on areas of technology most prevalent in the regulatory oversight provided by the NEB.

The report is not a technical thesis on the technologies described. Rather, it is intended to be an informative communication piece cataloging the major characteristics of the best technologies available and emerging in the foreseeable future. Moreover, this report is not a regulatory document that replaces expectations; it is meant to be a reference document for best available and emerging technologies as they relate to federally-regulated pipelines.

The adoption of new technologies as BAT takes time, even when proven effective. Many new technologies emerge initially as innovations towards cost reductions or economic opportunities; however, many technologies, and especially those that may provide public benefit but not necessarily any direct benefit to a company, may take years before they become sufficiently cost competitive to be widely adopted. BAT therefore are typically adopted either when their cost-benefit is competitive, or when required by regulation, or when particular circumstances make them compelling (e.g., for local acceptance of a project).

1.2.2 Scope: Environmental and Engineering Considerations of Pipelines

The mandated scope of this report is environmental and engineering considerations of pipelines that are regulated by the *NEB Act* and the *NEB DPR*. Specifically, it addresses:

- buried and above-ground pipe;

- equipment and other items attached to the pipe (principally mainline **sectionalizing valves** and **isolation valves**);
- pipeline facilities like pump stations for liquids and compressor stations for gas (environmental focus)
- the pipeline **right-of-way** (ROW); and
- areas beyond the ROW as appropriate for environmental considerations, including water course crossings.

It is important to note that current practices described in this report have generally been identified as BAT. Thus, in the report where BAT is not explicitly stated, the described practice constitutes current BAT. Similarly, where emerging technologies are not addressed in the report, it should be understood that beyond advancing BAT, no additional emerging technologies were identified. This absence should inspire research and development in these areas.

1.2.3 Defining Pipeline

The *NEB Act* defines "pipeline" as:

> a line that is used or to be used for the transmission of oil, gas or any other commodity and that connects a province with any other province or provinces or extends beyond the limits of a province or the offshore area as defined in section 123, and includes all branches, extensions, tanks, reservoirs, storage facilities, pumps, racks, compressors, loading facilities, interstation systems of communication by telephone, telegraph or radio and real and personal property, or immovable and movable, and works connected to them, but does not include a sewer or water pipeline that is used or proposed to be used solely for municipal purposes…

The Guidance to the *NEB DPR* provides the following guidance with respect to (or interpretation of) the *NEB Act* definition:

> pipe – difference between "pipe" and "pipeline";
> the definition of pipeline in section 2 of the *NEB Act* encompasses everything related to the pipeline, with all real property, which includes the ROW [pipeline Right of Way]. When the word pipeline is used, it includes the pipe *and* the ROW. The word "pipe" refers to the specific conduit through which **hydrocarbons** and other commodities are transported…

The Canadian Standards Association Standard (CSA) Z662-15* defines pipelines more restrictively as:

> those items through which oil or gas industry fluids are conveyed, including pipe, components, and any appurtenances attached thereto, up to and including the isolating valves used at stations and other facilities.

1.3 Method

This report was developed in two phases:

- ***Phase one*** used research and consulted with industry members, industry associations, academia, and government agencies to identify engineering BAT and emerging technologies related to pipeline construction, materials, and emergency management.
- ***Phase two*** expanded the initial report to consider more engineering factors and include an environmental focus. It combined research with internal and external consultation (from the same types of groups as Phase One) to identify BAT.

The information in this report combines research, NEB professional judgment, and information from both phases. Section 8 (Engagement Surveys) includes stakeholder responses about technological uptake and regulatory versus industry responsibility for BAT.

1.4 Overview of Federal Pipeline Regulation in Canada

Pipelines that cross provincial or international boundaries are regulated by the NEB. The NEB is committed to adapting to emerging technology and scientific advancements and we will continue to strive toward regulatory excellence in everything we do. The NEB operates within a mandate set by Parliament for the regulation of pipelines, energy development and trade. The NEB reports to Parliament through the Minister of Natural Resources.

The NEB exercises its regulatory mandate by, for example:

- regulating the construction and operation of pipelines that cross international and interprovincial boundaries;
- inspecting pipelines during their lifecycle stages;
- investigating pipeline incidents; and
- auditing individual pipeline companies.

Role of Management Systems

As required by the *NEB Onshore Pipeline Regulations* (*NEB OPR*), companies must establish, implement and maintain effective Management Systems and protection programs in order to anticipate, prevent, mitigate and manage conditions that may adversely affect the safety and security of the company's pipelines, employees, the general public, as well as property and the environment. Management Systems facilitate a systematic approach to effectively manage and reduce risk and include the necessary organizational structures, resources, accountabilities, policies, processes and procedures for an organization to fulfil all tasks related to safety, security and environmental protection. A carefully-designed and well-implemented Management System

* "Oil and Gas Pipeline Systems", which is incorporated in the NEB Onshore Pipeline Regulations.

supports a strong culture of safety, and is fundamental to keeping people safe and protecting the environment. Although the use of BAT and emerging technologies can be instrumental in risk mitigation, ensuring their use within an effective management system is important to best maintain the safety of people and the environment.

Developing Initiatives and Incorporating Advances
The NEB develops initiatives that support its mandate and facilitates the exchange of ideas and best practices that can improve design, construction, and operation standards.

Similar to the CSA Z662-1.8 clause stating: "it is not the intent of this Standard to prevent the development of new equipment or practices, or to prescribe how such innovations are to be handled", the NEB encourages the use of BAT and emerging technologies provided the company is able to demonstrate that the technology meets performance requirements and that safety to people and the environment is not diminished. Through this process, the NEB is able to make decisions and recommendations that represent the ever-changing interests and concerns of Canadians.

1.5 The BAT and Emerging Technology Initiative

The goal of this report is to identify the best available and emerging technologies used in federally-regulated pipelines. Since technology is a rapidly advancing field, this document is only a snapshot of BAT and emerging technologies in the year it was written. Future audiences should interpret its contents in this context and understand that the included content is not exhaustive.

A key early challenge was to suitably define BAT and emerging technology as it applies to the broad range of engineering and environmental considerations the NEB identified through research and engagement. There are a number of definitions for environmental BAT[1,2,3,4,5,6] but few have been developed for engineering. Research and consultation with engineering and environmental specialists led to the following definitions, which shaped this report:

Best available technology means the application of the most appropriate or required combination of measures and strategies to ensure the safety of people and **mitigation** of adverse environmental effects.

Best means effective in achieving a high level of protection of people and the environment.

Available means a commonly adopted or required technology with no excessive costs.

Technology is broadly defined and means a collection of techniques, skills, methods, and processes.

Emerging technology is technology that is currently being developed or field tested, and which can be reasonably expected to become BAT within a few years. To be included in this report, it is expected that field testing and experience will better identify and confirm the circumstances under which emerging technologies will yield better engineering and/or environmental performance and economic benefit than current measures. The emerging technology presented in this report has been generalized so as to not endorse a particular product or company.

1.6 Pipeline Lifecycle

The pipeline lifecycle is made up a series of stages. This report is structured to provide information on BAT at each of the following stages:

- 2.0 Design;
- 3.0 Pipe Manufacturing;
- 4.0 Pre-Construction Planning and Construction;
- 5.0 Commissioning;
- 6.0 Operation; and
- 7.0 **Deactivation** and **Abandonment**

Design and Pipe Manufacturing | Pre-Construction Planning and Construction | Commissioning | Operation | Decommissioning or Abandonment

Pipeline Lifecycle

Emergency Management

Emergency management is an important element that applies to various stages of the lifecycle:

- **mitigation** measures apply at the design and planning stages to mitigate leaks or ruptures (e.g., ensuring integrity of the pipe and having adequate emergency response procedures including an Emergency Response Plan); and
- **emergency response** applies when an incident occurs, most often during operation, but also during construction or deactivation and abandonment.

This report includes emergency management under the operation stage in the context of emergency response.

2.0 DESIGN

The design phase of a pipeline typically considers: pipeline capacity; stability and integrity; route; facility sites; and equipment choices and operability. Pipeline design also considers strategies to avoid or mitigate potential adverse impacts to ensure the safety of people and the environment. This can include consultation with other jurisdictions, Indigenous people, and landowners in order to better understand the interactive effects of the environment on the pipeline and the pipeline on the environment. The next sections give examples of engineering and environmental BAT.

2.1 Pipeline Design: Engineering Considerations

Pipeline design typically includes three phases:

- preliminary design to assess feasibility;
- Front End Engineering Design (FEED); and
- final design.

The design methodology depends on the size and nature of the project. BAT typically affects only the final design stage.

2.1.1 Feasibility Designs

Feasibility designs focus mainly on financial considerations and generally do not specify technology.

2.1.2 Front End Engineering Design (FEED)

If the operating company applying to build the project determines the project is feasible, it produces a FEED. The FEED must demonstrate that the project will meet a specific need for the Canadian public and not compromise public convenience, and it must include enough detail for the regulator[*] to be able to decide whether to recommend its approval to Parliament (in the case of the NEB).

The FEED may identify new technology and specify applications of innovative technologies such as **Alternative Integrity Validation (AIV)** or a **strain-based design** approach. However, the applicant will not work out the details until the final design; thus, BAT seldom go into the FEED.

If the regulator recommends approval, it will often impose conditions that companies must address in the final design.

[*] The Regulator's assessment considers project design and safety, environmental matters, socio-economic and land matters, impacts on directly affected Indigenous groups, impacts on directly affected persons, financial responsibility of the applicant, economic feasibility and the Canadian public interest.

2.1.3 Modelling for Final Design Conditions

The final design generally requires extensive modelling, computation, and calculation, and different processes and situations require different levels of design complexity. To model a final design, the operating company:

1. assesses the risks associated with possible failure scenarios;
2. performs a structural and strength analysis of the pipeline; and
3. determines the most appropriate design based on this analysis.

This section concentrates on best available and emerging technologies for risk assessments, structural and strength analysis, and resulting design types.

2.1.3.1 Assessing Risk

Risk assessments drive design decisions. Therefore, the operating company assesses potential risks for various stages of a pipeline's lifecycle to determine possible consequences and the likelihood of those consequences occurring.

During the design stage, operating companies:

- assess construction effects on populations and the environment; and
- suggest measures to minimize the likelihood of adverse effects.

Non-quantitative approaches are more appropriate for simpler cases,[*] for example:

- *a land use study* can determine the likelihood of residential encroachment on a pipeline, where the effects may be significant; or
- a *cost estimate* can determine whether to increase the reliability of pipe segments during the construction stage or later, during operation.

Quantitative Risk Assessment (QRA) methodologies are most appropriate for complex design uncertainties that risk, for example, a large spill into an ecologically sensitive area, or that could affect a population's drinking water. QRA is best where failure frequency data is robust and established software solutions are available.[†]

Emerging Technology

Even in relatively simple cases, QRA is emerging as a global technology due principally to the consistent rigour it brings to the assessment.

[*] For example, using a 5x5 matrix will usually suffice (as described in Z662-15, Annex B).

[†] Guidance on the use of QRA methods is given in CSA Z662-15, Annex O (Reliability-based design and assessment (RBDA) of onshore, non-sour service natural gas transmission pipelines).

2.1.3.2 Structural and Strength Analysis

Once the level of risk has been determined, designers must analyze the types of stresses the pipeline could experience. The method of analysis depends on the number and type of stresses.

In very simple cases, applicants can meet code requirements manually.[*]

Most realistic pipeline configurations require computer analysis, particularly with buried pipelines where pipe-soil interaction has a large effect on how the pipeline responds to external loads. For analyzing buried pipelines under combined internal pressure and external loads (such as **geotechnical** or thermal where deformation of the pipe can result in permanent deformation), nonlinear **finite element methodology (FEM)** that uses application-specific pipe elements is almost always required.

2.1.3.3 Design Types

Once they have analyzed the possible responses in terms of displacement, strain, and stresses in the pipeline, the designers decide the most appropriate type of design. These types include:

Stress-based design, to accommodate stresses that:

- remain essentially constant over time, such as the weight of the pipe and weight of the soil over the pipe; and
- are operational, as with internal pressure.

In this type of design, a maximum stress is set below the level at which the pipe would permanently deform. For many routine pipeline designs in Canada, stress-based design is sufficient.

Strain-Based Design

Most pipeline codes incorporate a stress-based approach.[†] This approach works well for simpler, routine piping configurations. However, buried pipelines are frequently subjected to loadings that produce stresses higher than those allowed by stress design. In these cases, a **strain-based** approach is required to ensure integrity of the pipeline.

Strain-based design accommodates environmental events such as slope movement, **subsidence**, and seismic loads, which can:

- incrementally add to the stress or strain; and
- permanently deform the pipe in a controlled manner.

It also:

[*] Such as those in CSA Z662-15.

[†] Including CSA Z662-15.

- specifies allowable deformation in the pipe by controlling allowable strains (so-called limit states) to a safe level;*
- requires more stringent control in weld quality, testing, handling procedures and monitoring during operation; and
- usually requires application-specific, commercially available software.†

2.1.4 Material Selection

The choice of material for pipe depends on ease of manufacturing, pipe size, expected load, cost and environmental considerations.

2.1.4.1 High-Strength Steel

High-strength steel results in thinner pipeline walls without compromising safety. Also an advantage is that thinner pipe is easier to weld during manufacturing and construction and has a lower cost. The last 30 years or so have seen significant improvements in high-strength steels.‡ [7]

Tough, high-strength steel is generally considered the BAT for pipe manufacture, however, careful process control is necessary.

- The pipe manufacturers' processes must maintain the pipe steel's toughness and weldability advantages.
- Workers must account for the thinner wall when transporting and handling it.
- Engineers must consider the thickness when designing for operational loads such as thermal loading and earth loads. A soda can offers a good analogy: it holds pressure from the fluid content, but easily crumples if squeezed externally because it is thin relative to its diameter.

2.1.4.2 Composite Pipe Material

BAT for pipe material continues to be:

- steel for larger diameter pipelines; and
- high-density polyethylene (joined by heat fusion) for smaller, low-pressure applications, such as well-field gathering lines.

---

* Pipe elements must be able to deform plastically once they reach the elastic limit. In these situations, design software must handle nonlinear response from large deflections, nonlinear pipe-soil interaction, and post-elastic behaviour in the pipe elements.

† Guidance on the application of **strain-based design** is given in Annex C of CSA Z662-15 (Limit states design).

‡ The process of simply hot-rolling plate and subsequently heat-treating the pipe has evolved into one involving thermomechanical rolling, which incorporates hot rolling, controlled cooling and heat treatment in one process. Combining micro-alloying and thermomechanical rolling resulted in higher strength steels with reduced carbon content (which improved the weldability of the steel). In the 1980s, thermomechanical rolling was further improved by incorporating accelerated cooling, which led to even less carbon content, but improved toughness—toughness being the property that controls brittleness and enhances resistance to damage due to the formation of cracks in the steel. More recently, adding molybdenum, copper and nickel has produced even higher strength steel without decreasing weldability or toughness.

Emerging Technology

- combining the two processes above—through composite pipe with a steel core, and polyethylene interiors and exteriors. This produces high-strength pipe with enhanced corrosion resistance, which is:
  - joined by mechanical fittings, rather than welding, to allow rapid installation; and
  - limited, at present, to pipe sizes up to Nominal Pipeline Size (NPS) 8.[*]

Composite wrapped over (lower-strength) steel pipe can achieve the equivalent strength of higher-strength steel pipe.

2.1.4.3 Reinforced Thermoplastic Pipe (RTP)

RTP is a hybrid technology that takes an inherently corrosion-resistant product (polyethylene) and applies it more broadly. This composite reinforces high-density polyethylene (HDPE) with high-strength fiber (such as glass or carbon) which is wound in oblique, parallel laminate layers, with HDPE on either side.[8]

Fiber-reinforced composites have been used as permanent pipeline repair methods for over 50 years. RTP leverages this operational experience.[9]

Emerging Technology

To deal with issues like corrosion, using composite materials in place of steel (such as reinforced polyethylene and composite reinforced steel) is becoming more acceptable and advanced. However, the products are currently limited to size NPS 6[†] or smaller.[8]

2.1.5 Preventing Corrosion

Coating the Steel

Buried pipes are susceptible to external corrosion from contact with moisture and minerals in the soil surrounding the pipe. The main way to prevent this corrosion is with an electrically and chemically resistant coating on the pipe. This coating separates the pipe steel from electrolytes in the soil. This separation prevents the pipe from functioning as an anode in an electrochemical cell, which would make it susceptible to corrosion.

Cathodic Protection

If the coating is damaged and pipe is exposed to the soil, the second line of protection is known as **Cathodic Protection** (CP). CP is the practice of negatively charging the pipe and situating positively charged anodes close to the pipe. The anodes sacrificially corrode and protect the pipe. The anodes must be replaced periodically.

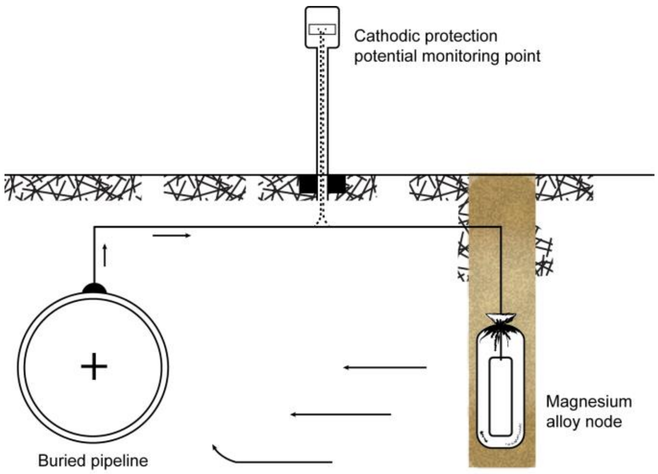
---

[*] NPS 8–outside diameter 219 mm.

[†] Outside diameter 168 mm.

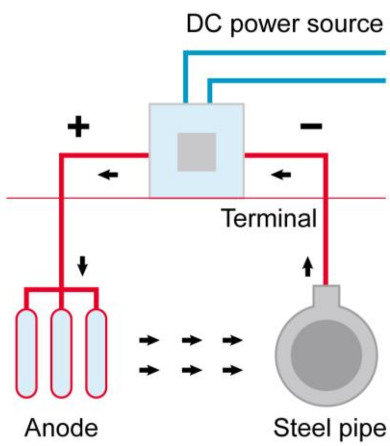
Two basic CP options are listed as follows.

- ***Galvanic:*** the anode material has higher electrochemical potential than the steel of the pipe, so the pipe is naturally cathodic relative to the anodes, and therefore less likely to corrode. The most common galvanic anode materials are magnesium or zinc alloys.



Example of Galvanic Current Cathodic Protection

- ***Impressed current:*** a negative charge is applied directly to the pipe and a positive charge to the anodes. This method is more common on cross-country transmission pipelines.



Example of Impressed Current Cathodic Protection

BAT for CP

The BAT in CP is impressed current, possibly with additional galvanic anodes at locations that require more protection. However, operating companies must limit voltage. Excessive voltage (greater than approximately 1.20 volts) can disbond coating.

2.2 Pipeline Design: Environmental Considerations

2.2.1 Environmental Assessment (EA)

EA is a planning and decision-making tool. The concept of BAT can be applied to the processes, practices, and tools of EA, and many of the technical planning, measurement, modelling, and design steps that contribute to good EA are covered elsewhere in this document. This section provides a high-level overview of some process elements that contribute to best possible EA, in the context of major Canadian pipeline projects. Although legislative and administrative rules may be altered from time to time, the objectives and values of good EA outlined below are likely to persist.

The objectives of an EA are to:

- minimize or avoid adverse environmental effects before they occur; and
- incorporate environmental factors into decision making.

An EA:

- identifies potential adverse environmental effects;
- proposes measures to mitigate them;
- predicts whether there will be significant adverse environmental effects after **mitigation**; and
- includes a follow-up program to verify the environmental assessment was accurate and **mitigation** was effective.

2.2.1.1 EA in the Context of Canadian Major Pipeline Projects

An EA is mandatory when the NEB is the responsible authority for a project that falls under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) Regulations Designating Physical Activities (for pipeline projects involving more than 40 km of new pipe). For pipeline applications under 40km, not designated under the CEAA 2012, the NEB conducts an EA as part of its duties under the *NEB Act* before making decisions on smaller pipeline projects not designated under the CEAA 2012.

"Environmental assessment" or "environmental and socio-economic assessment" (ESA) *can* mean any process that meets the objectives outlined at the beginning of this section. However, for major Canadian pipeline projects it often means processes required by statutes such as the CEAA 2012, or similar requirements in Provinces or Territories.

2.2.1.2 Some Best Practices for EA[*]

The EA process is the application of a series of principles and procedures established by institutions and practitioners beginning in the 1970s. Since then, EA legislation, regulations and

[*] See the NEB Filing Manual on the NEB website for more complete discussion on EA themes explored briefly in this section.

guidance has formalized the process, and optimization of EA remains a topic of active discussion[*].

Timeliness
An EA should be conducted as early as possible in a designated project's planning stage to:

- allow the proponent to consider the analysis during planning; and
- support better decision making by companies and regulators.

An early EA has benefits such as:

- avoiding or minimizing adverse environmental effects;
- opportunities for public participation and Indigenous consultation;
- increased protection of human health;
- reduced project costs and delays;
- reduced risk of environmental harm or accidents and malfunctions;
- increased government accountability and harmonization between government bodies;
- lessened probability of transboundary environmental effects; and
- informed decisions, contributing to responsible development of natural resources.

A clear process will make it more likely an EA is completed without unnecessary delays.[†]

The public needs a certain amount of time to learn about the project and how it may affect their rights and interests, to participate meaningfully in the process and process design, and to express their views and knowledge to decision makers. Like any regulatory process, EA involves competing demands for timely completion, cost, and quality. Pipeline operating companies and the public value speedy decisions that are fair, clear, legally sound, and that the public respects.

Time limits may be set out in legislation or by service standards. To ensure flexibility and fairness, mechanisms to "stop the clock" are typically implemented for circumstances beyond the applicant's or the regulator's control

Precautionary Principle
EA should incorporate a precautionary approach when assessing the project, guided by the following list of principles.

- Precaution helps detect, reduce and manage risk.
- Precautionary **mitigation** should be based on scientific and technical information. This information should be available to the public and tested through a public process.
- Precaution is appropriate when variability and unpredictability in the natural environment make environmental effects difficult to predict.
- Contingency planning and adaptive management tools facilitate dealing with findings of environmental monitoring that may reveal varied, unpredicted or unexpected outcomes.

[*] For example, see Johnston (2016) Federal Environmental Assessment Reform Summit Proceedings. West Coast Environmental Law.

[†] Reasonable flexibility (typically after hearing views from other participants) is essential to preserve fairness when participants have legitimate reasons for missing deadlines.

- Effective community engagement and follow-up environmental monitoring can verify or disprove the assumptions in the EA and help to reduce scientific uncertainty and unnecessary precaution over time.
- A public and transparent assessment process improves the precautionary approach.

Scope of the EA
Regulators must consider all aspects of a proposed pipeline project before making a recommendation. This includes technical, human, and cultural aspects, such as local, regional, and national perspectives from affected individuals, Indigenous groups, and other groups along the route.

Scoping is the foundation of an effective ESA. The scope ensures the assessment focuses on relevant issues, factors, and level of detail, including:

- the physical facilities and activities to include, and
- the biophysical and socio-economic elements likely to be affected.

The applicant's role in scoping includes:

- giving sufficient information to the NEB to fully understand the project;
- ensuring the ESA focuses on relevant issues and concerns, including those identified by affected parties, with an appropriate level of detail; and
- considering the factors set out in s.19 of the CEAA 2012 as applicable. The Board expects a complete ESA from an applicant, even for projects not governed by the CEAA 2012.

Scoping for any project, including major pipeline projects includes determining the scope of the project and the scope of the EA itself.

Filing Requirements
The regulatory filing requirements should be transparent and knowable in advance of the EA. The regulated company must submit all information as part of their application. The NEB's expectations and filing requirements for EAs are set out in its online Filing Manual. As the Board evaluates the application and receives public comment, it will often direct the company to file additional information.

Regulators do not typically need final design details during the EA. Many final engineering details can only be determined after the EA is concluded, the project has regulatory approval, and project construction has begun. As an early project planning tool an EA often results in conditions of approval which set out direction and expectations for, implementation of mitigation, any further information needs, or any further final design details.

Public Participation
The review process should be fair, open to the public, safe, respectful, and transparent. It should encourage and support meaningful public and Indigenous participation. This would typically include collecting oral traditional evidence, such as Indigenous community knowledge and testing the technical evidence filed. People should be able to share their information using a variety of methods (e.g., orally, in writing, by telephone or by videoconference, as appropriate).

This approach helps give all eligible participants opportunities to bring evidence and opinions, despite financial, work, and life commitments or distance.

Consultation aims to inform the public and potentially affected parties to:
- assist them to understand the project;
- provide opportunities to raise and understand concerns; and
- discuss how these may be appropriately addressed.

Thorough and effective consultation:
- is initiated by the company as soon as possible in the planning and design phases of a project;
- provides clear, relevant and timely information to potentially affected persons or groups;
- it is accessible to, and includes, all potentially affected persons or groups (participant funding is a best practice to help facilitate public participation in EA and certain regulatory proceedings);
- provides appropriate and effective opportunities for potentially affected parties to learn about a project and provide comments and concerns to the applicant;
- means the applicant is responsive to the needs, input and concerns of potentially affected persons or groups; and
- continues through all phases of an approved project.

Hearing directly from those who may be affected by the project, ideally in the language of their choice (with simultaneous interpretation as necessary), is key when considering sustainable development. Best practice for public hearings could include:
- public input on the draft list of issues, additional information requirements, and locations of hearings;
- oral comments on the process for hearings;
- public information sessions to explain the process and opportunities to participate;
- process advisors to assist participants throughout the hearing process;
- opportunities to hear oral statements and oral evidence from people potentially affected by the project, and to enable Elders and First Nations to share their oral history and traditional knowledge;
- online workshops to help participants prepare for participating;
- transcripts and documents promptly and publicly available (e.g., on regulator’s website); and
- live webcast of proceedings (i.e., audio or video).

A proponent should consider input from stakeholders such as:
- landowners and tenants owning or residing on land potentially directly affected by, or adjacent to, the ROW where the construction and operations are to occur;
- landowners and tenants residing in the project corridor;
- those who live or work near the project and who could be physically affected by construction, operations and associated activities;
- those who have established environmental, cultural, social, or economic interests in the project;

- those who have particular knowledge that would be helpful for the project; and
- those who have a statutory mandate to manage areas or activities that the project might affect.

Quality and effectiveness of a proponent's public engagement could be evaluated in terms of:
- how the public responded to opportunities to consult on the project;
- how the proponent considered and addressed the concerns of potentially affected parties; and
- how input from the public influenced the project's proposed design, construction and operation.

The proponent's public engagement is an essential and ongoing activity throughout the project's lifespan.

2.2.1.3 Technical Considerations

Biophysical Effects
The NEB Filing Manual outlines key biophysical and socio-economic effects that companies should consider in a pipeline EA, subject to appropriate scoping.

Cumulative Effects Analysis
The application that a company submits must capture baseline information, project description and project-specific **mitigation** measures, with enough detail to show the project's residual effects (those effects remaining after **mitigation** measures have been implemented).

A cumulative effects assessment differs from a conventional project-specific effects assessment in that it typically includes:
- larger geographic study areas not constrained by jurisdictional boundaries;
- longer time frames; and
- environmental and socio-economic effects of physical facilities or activities that may not be directly related to the project (e.g., upstream or downstream facilities, a proposed highway project or residential sub-division in the study area, ongoing forestry or agricultural activities).

The scale of the cumulative effects assessment and the level of effort to create it should be appropriate to:
- the nature and context of the project;
- its potential residual effects; and
- the environmental and socio-economic setting (e.g., more detail may be required when the region anticipates or has had rapid or intensive development, or the project includes particular environmental or socio-economic sensitivities or risks, such as significant Indigenous traditional use).

Valued Ecosystem Components and Effects Analysis
EAs typically use a "valued component" approach, which chooses and analyzes certain practical, biophysical and socio-economic elements called Valued Environmental Components (VECs) or

Valued Socio-Economic Components (VSCs). This makes it possible to assess project-environment interactions more precisely, particularly those the public or Indigenous groups may be concerned about.

Valued components could be elements from the NEB Filing Manual[*]. The valued components used for a project must:

- capture possible effects from the project over time;
- be measurable; and
- have baseline data with which to draw comparisons with future conditions.

The analysis should clarify:

- where there is uncertainty about project-environment interaction; and
- if more information is needed to predict the project's effects.

The assessment of effects should identify any residual effects left over after the application of project mitigation. In turn, residual effects then need to be carried forward into a cumulative effects assessment.

Ultimately effects are then assessed for their significance using appropriate criteria and defined ratings for the criteria.

For more information, consult the NEB Filing Manual and the Canadian Environmental Assessment Agency's *Operational Policy Statement - Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*.

Adaptive Improvement of Project Design

Applicants typically refine the project's design during the EA process in response to participants' views, questions and advice. New information and analysis in the EA also allows applicants, the public, and the regulator to evaluate new or innovative **mitigation** measures.

Follow-up and Monitoring

EA of major pipeline projects typically involve predicting complex biophysical system behavior years into the future. Some uncertainty is inevitable and the EA's conclusions and recommendations must accommodate this fact. Projects can follow up with monitoring and research once the pipeline is operating to minimize the potential development of adverse project impacts on people, communities, and the environment. These follow-up data can also be used to improve future assessments.

2.2.1.4 Species at Risk

Species at Risk are those species on Schedule 1 of the Species at Risk Act *(*SARA) and include: lichens, mosses, vascular plants, molluscs, arthropods, fishes, amphibians, reptiles, birds and mammals. Schedule 1 also includes designations for subspecies and specific populations. As of July 2016, 521 species were designated on Schedule 1 of SARA, and the list is updated regularly.

[*] Table A-1 of the NEB Filing Manual

There are numerous technologies to mitigate the impacts of projects on species at risk. However, the extent to which these technologies may be required vary widely across provinces and territories. Some technologies are legislated (e.g., *Fisheries Act*, provincial and territorial wildlife acts, *Migratory Birds Convention Act*, British Columbia *Oil and Gas Activities Act*); others come from resource management guidelines and best practices.

The following list of strategies aids in selection, development and implementation of BAT to mitigate impacts on Species at Risk.

1. Reviewing the Species at Risk Public Registry to determine which species overlap with the proposed development. Applicable provincial and territorial registries (e.g., Conservation Data Centers) can help determine overlap and locate management planning documents if available.
2. Reviewing available recovery strategies, management plans, and action plans for the potentially affected species. The intention here is to design based on consideration of:
    - the objectives of those documents;
    - the causes to or threats of decline in the species; and
    - available definitions of critical habitat or the biophysical attributes that describe critical habitat.

    It is then possible to use available tools (e.g., **desktop reviews**, field surveys, Geographic Information System (GIS) mapping) to evaluate potential project effects and opportunities to avoid or reduce impacts.
3. Determining if the project is likely to impact a species at risk, and whether the development would be contrary to the objectives of recovery or management.
4. Following the **mitigation** hierarchy of avoid, reduce, restore, offset.
    - Avoidance can be achieved by evaluating routing alternatives, adhering to seasonal **timing windows** (see section 4.2.3, Construction Timing), and establishing and adhering to setbacks around important features (e.g., rare plants, active bear dens, bat **maternity roosts** and **hibernacula**, wetlands that support at-risk amphibians).[*,10]
5. Developing a project-specific plan, such as an EPP that describes which **mitigations** will avoid, reduce, restore or offset an impact to a species at risk.
    - Standard **mitigation** measures (e.g., seasonal timing restrictions, setbacks) may be sufficient to alleviate potential impacts on Species at Risk.
    - Some species, such as woodland caribou, may require a species-specific management plan to fully describe the kinds of standard and non-standard **mitigation** and monitoring that will be implemented.

[*] Most information on timing restrictions and setbacks is available on federal, provincial and territorial government websites. It can also be found in federal recovery strategies, management plans and action plans, as well as provincial or territorial management or planning reports. See endnote 10 for one example.

6. Monitoring the effectiveness of non-standard **mitigation** using scientific approaches to predict the outcome, then testing the predictions (hypothetico-deductive methods), particularly for methods that are not well-tested or demonstrated to be effective.[*]

   Advancing research on Species at Risk is contributing to a better understanding of behavior, population trends, migration patterns and susceptibility to disturbance. In turn, this can allow better route planning, construction timing and **mitigation** measure selection. Regulatory conditions requiring proponent monitoring of project impacts may sometimes also provide data to further contribute to the knowledge base on individual species.

2.2.1.5 Caribou Habitat Protection and Restoration

There is an urgent need to develop and implement effective measures to protect and restore caribou habitat, in response to widespread declines in caribou numbers and evolving federal and provincial species at risk requirements and guidelines. Many mitigation measures used to lessen effects on caribou focus on restricting access[11,12,13] restoring habitat,[14,15] and **offsetting**.[16]

Caribou

Access Management
Managing human and predator (e.g., wolves) access along linear features is one of the most important measures to mitigate adverse effects on caribou. BAT examples include using **rollback** (i.e., a combination of logs, stumps, rock and soil), **berms**, and **mounding**. It is important that any access control measures be applied over the entire width of the linear feature so that it cannot easily be circumvented. Preventing the establishment of trails is key.

Habitat Restoration
Habitat restoration consists of measures above and beyond normal ROW post-construction reclamation measures (seeding or natural regeneration), with the intent to speed up the restoration of the ROW to a state comparable to adjacent forest ecotypes. New technologies which show promise include site preparation techniques (e.g., seedling plantings, including winter planting, and **mounding),** whether on its own as well as combined with the planting of seedlings.[15]

[*] It is useful to evaluate the effectiveness of **mitigation** on established targets or endpoints, such as seedling survival rates, community composition or measures of expected difference among treatments. Where targets are not met, it is helpful to develop an adaptive management framework to describe remedial measures for achieving effectiveness targets.

Offsetting
After avoidance, minimization and on-site ROW restoration are exhausted, **offsets** can then be used to account for residual project effects. **Offsets** can include off-site restoration, land securement, conservation covenants.[16] There is considerable literature on the principles and challenges around the development and implementation of offsets[*].

Emerging Technology
Line-of-sight management is a practice still being assessed as to its potential effectiveness in habitat restoration and caribou protection.

Long sight-lines may be reduced naturally where routing traverses appropriate topography (e.g., hills) and where a ROW changes direction (i.e., **line-bending**). In terms of BAT line-of-sight restoration measures these can include the use of Horizontal Directional Drilling (HDD) or boring at intersections to preserve existing vegetation barriers, berms or rollback of sufficient height, the bending or partial felling of adjacent trees, and the use of constructed visual barriers. Constructed barriers may require some maintenance. The planting of tree seedlings is also a long term measure but as with planting for access control or restoration it will be some years before it becomes effective. Current research suggests an effective line-of-sight may require a height of approximately 1.5 metres.

For all caribou habitat related measures monitoring is important. Monitoring is used not only to ensure implementation, but to assess effectiveness of the measures implemented and any assumptions. With monitoring and adaptive management BAT can be further refined. **Light detection and ranging** (**LiDAR**) and remote cameras are technologies being more commonly adopted and which can be used in measuring the effectiveness of access and restoration **mitigation** where implemented and comparing this to baseline conditions, unmitigated ROWs, and undisturbed forest areas.

2.2.2 Route Selection and Facility Siting

Routing and siting are the most significant determinants of a project's environmental effects.[17] While routes typically use pre-determined start and end points (e.g., initiating and **delivery terminals**), surface facility locations such as valves, compressors and pump stations, may be more flexible, subject to certain engineering constraints.

2.2.2.1 Route Selection Process

At a high level, the route selection process includes: [18,19]

- establishing the control points (locations with no or very limited alternatives);
- identifying **environmental constraints**, particularly those to avoid (e.g., wildlife corridors, archaeological sites, wetlands);
- identifying shortest route that, as much as possible, avoids sensitive environmental and socio-economic constraints, and at the same time does not require excessively complex construction methods;
- identifying and evaluating alternative routes; and

[*] See Poulton (2014), Biodiversity Offsets: A Primer for Canada.

- selecting the preferred route.

When selecting the route, applying companies consider potential effects on the environment, constructability and economic factors, and typically input from stakeholders. After selecting the route and siting the facilities, the company evaluates interactions with environmentally sensitive areas, and then performs adjustments if they are warranted and feasible.

2.2.2.2 Routing and Siting Principles

Examples of environmental routing and siting principles include: [17,20,21]

- minimizing pipeline length;
- constructing parallel to, or incorporating in existing linear developments (e.g., the ROW of other pipelines, all-weather roads, electrical transmission lines and rail lines) or other cleared areas (**cut-blocks**, existing utility corridors);
- selecting routes and facility sites that allow for future expansion;
- avoiding environmentally sensitive areas such as nests, dens, staging and calving areas, or unstable terrain or landscape features that are difficult to **reclaim** (e.g., peatlands);
- minimizing watercourse and wetland crossings, especially high-risk **watercourse** crossings;
- avoiding areas with Species at Risk; and
- avoiding known archaeological and historical sites and areas of high archaeological and palaeontological potential.

2.2.2.3 Benefits of Existing Linear Developments

The oil and gas industry aims to parallel or incorporate existing linear developments (as defined above) for a number of reasons, such as:

- reducing the amount of disturbed land;
- reducing cost;
- improving operability;
- reducing the need for new access; and
- reducing the number of landowners affected and number of agreements that need to be reached.

Linear development has prompted innovation such as narrower or shared ROW to allow co-location with power lines or other utility corridors. Developing new **greenfield** routes is often a last resort when parallel routes are not constructible or feasible due to additional length and cost or public interest.

2.2.2.4 Best Routing and Siting Solutions

GIS software makes it possible for environmental considerations to guide pipeline route selection and facility site planning.[22]

GIS is used:

- most typically to produce maps showing multiple route options (these maps usually identify areas to target or avoid and are important during both preliminary corridor selection and the ROW and facility site size and selection, i.e., micro-routing);
- to connect a place on a map to digital information about that area,[22] which allows operating companies to analyze route options as they relate to environmentally sensitive areas and features;
- during routing and siting to map the project plans to the **environmental constraints** that apply to the project type, location, product being transported, local regulatory regime, and stakeholder interests, among other factors; [*]
- to derive **quantitative metrics** (e.g., total hectares of old growth forest) and mapping (e.g., constraints maps, heat maps, and no-go areas);
- to derive predictions for incidents based on existing data sets (e.g. prediction of the spread of a fire using wind direction, vegetation and terrain data, or predict affected area of a pipeline spill by interpreting the terrain and volume of liquid) and generate maps related to these predictions; and
- possibly to automatically derive or select potential routes (e.g., the Electric Power Research Institute (EPRI) model used in transmission line siting); [23] however, it is more common for interdisciplinary experts to evaluate and select routes, supported by GIS-derived metrics.

GIS Information Sources and Updates

Initially, environmental information for GIS comes from sources such as federal and provincial databases and commercial vendors. As routing and siting is refined, trained personnel conduct environmental field surveys to assess site-specific issues and define appropriate mitigation measures. In order to refine siting and routing in real time**,** field-based data are linked to the project GIS to upload and use.

Emerging technology and new applications for existing technology include:

- increasing efficient ways to capture and transfer data to assess, refine and select routes and sites, including better image quality (e.g., **LiDAR**);
- using **unmanned aerial vehicles** (UAVs) to assess routing factors (including **geohazards** such as landslides, mud flows) and constructability; and

---

[*] GIS typically layers digital information such as:

- known locations of listed species (e.g., nests, dens, **leks**, rare plant locations, etc.);
- key habitat features (e.g., wetlands, **staging areas** for migratory birds, breeding habitats, ecologically sensitive plant communities, etc.);
- **watercourses** that might require special crossing processes or timing constraints; and
- parks and protected areas, recreational areas, or land use planning areas.

- capturing data and assessing applications based on tablet and web-GIS (these are becoming standard tools for pipeline routing and are continually being upgraded to be more functional and accessible in both the field and office).

2.2.3 Reducing the Project Footprint

In general, minimizing pipeline ROW widths and associated workspace, (the **project footprint**), reduces adverse environmental effects.[21]

2.2.3.1 Effect of Pipeline Diameter

Pipeline diameter to a large extent determines the width of ROW and the footprint, which in turn influences size of construction equipment and land needs to safely build and operate the pipeline.[24] Proposed construction techniques determine initial workspace requirements (e.g., trenched vs. **trenchless watercourse crossings**); however, these requirements change if necessary based on **environmental constraints** identified during routing, geo-technical survey and facility siting.

2.2.3.2 Design Strategy

Pipeline ROWs and associated workspaces can be explicitly designed to reduce the size of the **project footprint**. Examples include:

- selecting routes that avoid features that require additional workspace, such as steep or unstable terrain;
- co-locating or overlapping ROWs or workspaces with adjacent pipelines or other linear features;
- moving ROW or workspace features like **logging decks** out of sensitive locations (e.g., wetlands, wildlife habitat features or vegetation that may be difficult to **reclaim** if disturbed);
- reducing **stripping** width to trench-line or **ditch and spoil** only, to avoid disturbing vegetation across the entire ROW;
- mowing vegetation when possible instead of **grubbing** and blading, to keep topsoil, root systems and seed banks intact, which accelerates natural recovery after construction; and
- using **HDD**, **direct pipe** or other trenchless technologies to install the pipeline under sensitive features, for short distances. This eliminates surface disturbance.

2.2.3.3 Access Strategy

Insofar as access roads are themselves part of a project and its footprint, reducing the amount of off-ROW access also reduces the overall **project footprint**. Access-related environmental **mitigation** design measures include:

- routing the pipeline so that public highways and existing roads and trails can be used to access construction;
- using minimal disturbance access trails wherever possible to avoid or reduce the need for graded access roads;
- using temporary access mats;
- narrowing and reducing travel lanes along the ROW to one-way over short sections; and

- reclaiming and revegetating access roads after construction (if not required for operations).

Emerging Technology
Geogrid roads use **synthetic** materials to reinforce existing soil materials, reduce permanent access road widths, and decrease the amount of **aggregate material** needed provide access to construct, and to maintain the pipeline. In addition, at station sites, **geogrid** is used to reduce the amount of imported clay or **aggregate** relative to traditional construction methods.

2.2.4 Equipment Choices

The design of facilities and **infrastructure** influence the degree of disturbance to wildlife or humans in areas with important wildlife habitats and larger population centres. Design decisions also determine what kind of construction equipment the project requires, and this influences level disruption during the construction phase. For example:

- construction and operation noise and light **mitigation** is best incorporated at the design phase because it is difficult to retro-fit; and
- facilities designed to operate remotely using cellular, radio, or satellite Supervisory Control and Data Acquisition (SCADA) systems reduce personnel visits to the site, reducing potential stress on wildlife during operation.[21]

These construction and operation **infrastructure** decisions relate to the placement of pipeline valve sites, launcher-receiver sites, meter stations and compressors and pump stations.

Section 4 (Pre-Construction Planning and Construction) discusses these factors more fully. The following examples focus on installed **infrastructure**.

2.2.4.1 Reducing Air Emissions (Including GHGs)

It is possible to reduce Greenhouse Gas (GHG) emissions with:

- low nitrogen oxide burner technology to reduce emissions of nitrogen oxides during fuel combustion; [25]
- efficient **flaring** equipment or compression equipment to burn or contain the gases released during maintenance **blowdown** activities; [26]
- **vapour recovery** to capture **fugitive emissions** of **volatile organic compounds** at facility sites; [2,25]
- electric-powered (vs. **hydrocarbon**-fuelled) variable frequency drives for compressor engines, **amine regenerators**, pump stations and other equipment; [21] and
- **floating roof tanks** to store liquid **hydrocarbon**.

2.2.4.2 Storage Tanks

Air emissions from **hydrocarbon** storage tanks, valves and fittings generally contain methane, **volatile organic compounds** and **polycyclic aromatic hydrocarbons (PAHs)**. Emissions can occur during storage, loading and unloading of tanks and other storage vessels. Reducing emissions can be achieved by installing vapour capture equipment on internal **floating roof tanks** (IFRT). These vapour capture systems can either direct the gases to a flare or capture the gases for other use.

Environmental BAT for storage tanks include:

- tank sealing technology to minimize emissions over the long term; [27]
- reflective paints to reduce heating of contents, which reduces **volatile organic compound** emissions; [27]
- valves that can be remotely closed in the event of a spill; and
- valves and fittings that minimize potential for leaks. [2,25]

Emerging Technology

Emerging technology for pipeline and facilities is being directly incorporated into projects at the design stage and are often tied to asset management needs over the life of the project. These technologies include:

- ***fiber optic sensing technology*** that facilitates real-time, early detection of pipeline and facility leaks using glass (or plastic) fibers to transmit data; [28] and
- ***fiber optics on storage tanks*** to monitor the status of floating roofs and prevent over-filling.[*]

Other technology may be implemented on a case-by-case basis, for example, technology to generate power from solution gas that would otherwise be flared or vented [29] or heat recovery on a gas turbine compressor. [30]

[*] These design options become an integral part of Leak Detection and Repair (LDAR) programs, which are discussed in section 6.2.9 (Air Emissions Management).

3.0 PIPE MANUFACTURING

Pipe manufacturing includes construction of the physical pipe, which is usually completed before it arrives at the location where it will be used. Manufacturing considerations include:

- pipe material;
- welding practices used to form the pipe; and
- the type of coating used to protect the pipe.

Eco-friendly materials are discussed in the context of pipe manufacturing and facility construction.

3.1 Pipe Types (Including Seam Welding)

Broadly, two types of steel pipe used in transmission pipeline construction include:

- ***Seam-welded***, in which a flat steel plate is formed into a cylinder and welded along the abutting free edges (seam); and
- ***Seamless pipe***, formed directly from a steel ingot, which is first pierced to form a thick cylinder (called a "billet") and then progressively reduced, by forging, to form a thin-wall pipe.

Depending on specific manufacturing techniques, seamless pipe is available up to NPS 28,[*] although seam-welded pipe up to NPS 48[†] is common in the pipeline industry. Larger diameters up to at least NPS 72[‡] are also available, but are used less often.

Pipe Manufacture

Both seam-welded and seamless pipe can be considered BAT. For seam-welded pipe, the quality of the seam weld is critical. Earlier welding techniques that borrowed from water and other low-pressure pipeline applications (such as forged lap joints) are no longer used. Modern methods (dating from the 1980s) when properly applied and inspected in the steel mill, produce a sound seam weld with the same or greater strength as the pipe body.

Seam-welded pipes, formed before 1970 by low frequency electric resistance welding, are still in operation, however, they are no longer manufactured. Since this method has been found to introduce flaws into the seam weld, particular attention (in the form of in-service integrity monitoring) remains necessary to ensure the soundness of the weld.

3.2 Coatings

Coating applied to the pipe in the **pipe mill** is the main protection against external corrosion. The coating must:

- adhere well to the pipe;

[*] Outside diameter 711 mm.

[†] Outside diameter 1219 mm.

[‡] Outside diameter 1828 mm.

- be flexible to allow bending of the pipe without damaging the coating;
- have adequate electrical and chemical resistance; and
- be able to resist load from movement of the soil (called "soil stress").

Early coatings were mainly based on coal tar and asphalt derivatives, and many remain successfully in service today. Field-applied polyethylene tape was used for a period of time, but operating companies found it disbonded in a way that impeded CP and allowed electrolytes from the soil to contact the pipe, generating an environment susceptible to s**tress corrosion cracking** (**SCC**).

Pipe Coating

Many modern coatings are available. The BAT is to select one that suits the degree of impact resistance and flexibility the pipeline segment needs. Some examples include:

- ***two-layer polyethylene***, a good general-purpose coating that has been available since the 1950s;
- ***multilayer coatings***, available where greater impact and abrasion resistance is required; and
- ***fusion bond epoxy***, a high-performance coating with the advantage of not shielding CP if disbonded, which makes it particularly suitable in locations where conditions make the pipe susceptible to **SCC**.

Emerging Technology

Efforts are underway to identify how to make pipeline coatings more environmentally friendly, by removing environmentally harmful components such as **volatile organic compounds** (VOCs) that can be released into the atmosphere while the coatings cure.

3.3 Storage

Major damage considerations when storing pipe are:

- ultraviolet (UV) and other environmental damage to the coating;
- corrosion damage due to uncoated steel being exposed to the atmosphere; and
- local overstress of the pipe wall due to loads from wood skids and blocking used to support and separate the stacks of pipes.

The industry understands these considerations well. If operating companies account for them correctly, they do not need any additional technology.

4.0 PRE-CONSTRUCTION PLANNING AND CONSTRUCTION

Pre-construction and construction phases of a pipeline system can adversely affect a number of environmental elements. These include:

- atmospheric (e.g., air quality, **GHG** emissions);
- acoustics and light;
- soils;
- geology and terrain (e.g., landslides);
- vegetation (e.g., old growth forests, rare plants);
- wildlife (including species at risk);
- water quality and quantity;
- fish and fish habitat;
- heritage resources; and
- **groundwater**.

This section includes examples of BAT and emerging technologies to mitigate adverse environmental impacts based on a range of materials and strategies.

4.1 Pipeline Pre-Construction Planning and Construction: Engineering Considerations

Pipelines can be either above-ground or buried. This report in its entirety concentrates on BAT for the more common buried pipelines (especially large diameter transmission pipelines), however, the following situations are discussed:

4.1.1 Above-Ground Pipeline

Above-ground pipeline includes ground movement and river crossings.

Movement
Above-ground construction separates (decouples) the line from the surrounding soil in areas of sharp or uncertain slope movement and zones of extreme seismic activity.

River crossings
Above-ground pipelines can use pre-existing road or rail bridges to carry pipe, which avoids the expense, construction, and environmental consequences of a conventional crossing under the **watercourse**.

If there is no pre-existing bridge, an above-ground or "aerial crossing" can avoid ecological, hydrological or geological challenges of conventional crossings.[*] Aerial crossings typically require more maintenance than other types of river crossings, including periodic "tuning" of suspension cables.

Most pipeline projects have several construction phases. The following sections detail the current technologies and methods for each phase.

[*] See discussion section 4.1.12 (Horizontal Drilling and Microtunneling).

4.1.2 Buried Pipeline

Marker indicating a buried pipeline

Burying pipelines minimizes land use, and has security, protection and aesthetic advantages.
The pipeline construction industry has worked extensively to make this process as safe and efficient as possible. While technology, machinery and equipment in the pipeline industry have changed significantly over the last 50 years, today's machinery looks relatively similar to that of decades ago. Specialized groups such as welding or coating crews perform many small tasks repeatedly in a production line approach. Ideally, this strategy maintains consistent expertise, quality, and production levels, and minimizes repairs and delays.

4.1.3 Brushing, Grubbing and Stripping

One of the first construction activities is clearing vegetation from the pipeline ROW, often called brushing, but also called **grubbing** and stumping.[*]

Brushing involves cutting trees, **levelling** shrubs, and other vegetation that would interfere with constructing the ROW. Typically, brushing is done with logging machinery (e.g., feller-bunchers, bulldozers, chainsaws), mowers, and excavators. Large debris that does not fit into the spoil pile is segregated and burnt or hauled away.

Stripping is the removal of top soil to expose **subsoil** and create a somewhat level working surface. Best practices and legislation for **stripping** conserve topsoil through separate activities. First, the (organic) top soil is skimmed or stripped from the ROW. Then, as the **trench** is dug, the **subsoil** is stored in a separate location. Once the pipe has been lowered into the **trench** it is **backfilled** (meaning re-filled) with the **subsoil**, and then finally the whole area is re-covered with the stored top soil.

Separating topsoil has widened the pipeline construction area. A typical ROW now has a topsoil pile, an area for the excavation spoil and width for the **trench**. The working space comprises an area for stringing out the pipe material to be welded, space for the welding equipment, side booms and excavators, and an overlap area for equipment to be moved around or used in the case of emergency.

---

[*] Environmental considerations related to the practices of clearing the ROW and managing topsoil are numerous, and are described in section 4.2 (Pipeline Pre-Construction Planning & Construction: Environmental Considerations).

4.1.4 Trenching

Trenching involves installing pipe by trenching or digging a slot in the ground with machinery. Transmission pipeline projects commonly use wheel trenching, a continuous cycle of buckets on an assembly line that scrape the **trench** face and deposit soil nearby. Resulting trenches are typically clean and uniform with high vertical walls.

Wheel trenching is particularly useful if the **trench** path does not intersect with utility crossings (e.g., underground cables, water lines, sewer lines). When it does, the operating company must temporarily raise the **wheel trencher** to protect the underground utility and lower it again after the obstacle. If this happens often, it can slow the trenching process. It also is problematic when overhead utilities (e.g., power lines) and underground utilities coincide.

Wheel Trencher

Trenching technology has evolved into many versions that deal with utility crossings and other requirements, such as depth of the cut. One version includes an elliptical chainsaw with an adjustable depth and a low height. Another version has a smaller circular digging wheel that cuts in an up-and-down motion, which extends its reach and results in deeper trenches.

In general, wheel trenching (using a device also known as a **bucket wheel**) is the best available and most often used technology, terrain and clearance from other utilities permitting. However, various trenchless installation methods are available, such as ploughed-in construction where the pipe is fed through the toe of the plough blade making the **trench**. This form of construction is particularly suited to small diameter steel pipe and high density polyethylene pipe. These methods are attractive because of speed, ease of pipe burial and reduced ROW width. There appears to be no emerging extension to larger diameter steel pipe. However, this method r might well be further developed where decreasing the ROW width is necessary or desirable.

4.1.5 Pipe Storage and Transportation

The potential for damage during storage is covered in section 3.3 (Storage).

Pipe Transportation

Transporting pipes carries damage risks similar to storage risks. However, pipe can be handled so as to minimize any risk of damage. The main concern is that during transportation pipes can be subjected to repeated lateral (vertical) motion when the vehicle carrying it goes over uneven terrain. This repeated motion can form fatigue cracks (which can grow to failure when the pipe is put into service), and "double-jointed" pipe is particularly prone due to its greater length (and therefore greater flexibility) and the presence of the girth weld joining the two joints.*

In these cases, the BAT is to calculate the dynamic stresses due to typical highway transportation loads, then design and place supports and separators to avoid fatigue damage.

4.1.6 Stringing

Stringing, or placing pipe material on the ROW, begins when sufficient space has been cleared and the pipe is aligned on the ground, staked out by markers to keep ahead of the pipe placement.

Stringing

Stringing of the pipeline is the method of organizing coated pipes in the field to optimize joining and laying. Pipes are laid on wooden supports (skids) with predetermined spacing to minimize **ovalization** or excessive stress. This process requires enough workers to coordinate lifting and lining up. Handling the pipeline material carefully is essential to avoid the numerous opportunities for damage that could develop into injurious defects during the operating life of the pipeline. Pipe may be handled a number of times during manufacture and storage, coating and storage, transportation and storage, and other construction-related activities.

Current practice constitutes BAT. Apart from improvements in operating equipment, there is no notable emerging technology related to stringing.

4.1.7 Bending

Cold Bending

Bending (if required) occurs between stringing and welding. “Cold bending” allows the pipe to remain at a constant depth as the surface of the ROW undulates. This process accommodates gradual changes in elevation and alignment in the field. A bending machine uses hydraulic rams to forcibly bend the pipe beyond the plastic limit of the steel. The pipe deforms to the point that it springs back to the required bend radius rather than to its original straight shape. A useful analogy is to picture straightening and bending a paper clip.

Hot Bending

Larger changes in direction and corners with a tight turning radius require pre-fabricated bends. These bends are most often shop-fabricated. The process entails using induction coils to heat and

* This type of pipe has two lengths (pipe joints) girth-welded together in the **pipe mill** to reduce the number of welds necessary to make on site. However, the length of these double joints and possible small defects in the girth weld can be conducive to fatigue cracks in or near the weld.

then bend a straight piece of pipe, followed by a quenching or cooling period which stabilizes the pipe's material properties. A further heat treatment may be necessary to stabilize the pipe's material properties, like strength, yield and toughness. To determine if this additional treatment is necessary, one or more of the production bends representative of the entire bending procedure undergoes a final mechanical test.

Other methods can form the shape of these so-called "hot bends." For example, steel plates can be heated and formed into open half bends; the two halves are then welded along the intrados (inside seam) and extrados (outside seam) to form the completed bend.

Current practice constitutes BAT. Apart from improvements in operating equipment, there is no notable emerging technology.

4.1.8 Welding and Weld Inspection

Once the individual pipes or "pipe joints" have been bent to fit the terrain profile, they are welded together to form the length of pipeline that is lowered into the **trench**. The entire weld process, including welding procedures and qualification of the welding procedures, is developed in the design stage. There are two types: "stick" or manual welding and mechanized welding.

4.1.8.1 Manual and Semi-Automatic Welding

The final quality of the weld depends highly on the welder's skill, who must maintain the heat input into the weld by keeping a consistent pace—using the right positioning, welding consumable and generator settings.

A welder on a large diameter pipeline may take hours to complete a single weld. With many variables to control, there is potential for a poor weld, especially when completing it may require multiple passes, each with setting adjustments. The welder must ensure:

- the weld is uniform;
- the weld has no contamination, gas pockets or cracks; and
- the structure of the surrounding material has not been compromised from the heat from the welding.

Any deviation from the qualified welding procedure could result in flaws. Flaws may develop into injurious defects during the operating life of the pipeline. This type of welding is generally limited to repair work, tie-ins, small diameter pipe and/or short pipeline lengths.

Manual Welding

Manual or semi-automatic welding is often aided by the use of automatic internal line-up clamping systems. The key advantages are that:

- internal line-up clamps allow better access to the welding area from the exterior than external clamps do; and

- there are no obstructions to work around, as can happen with the welding consumable in the manual process.

Once the weld is complete, the clamping system is released and the welder continues to the next weld.

4.1.8.2 Automatic or Mechanized Welding

An internal line-up clamp system can also be fitted with automatic or mechanized welders to weld the **root pass** from the inside of the pipe. The **root pass** is the first layer of weld material that joins the two pipes. Subsequent passes fill the joint from the outside of the pipe, usually by mechanized welders. This type of welding is generally employed in large-diameter, long distance pipeline construction.

Regardless of welding system, it is important to know that all welding must meet a welding procedure specification. The specification is developed by qualifying the welding procedure by both non-destructive inspection and destructive testing of a sample weld or welds to ensure the procedure has the required properties. Welders train to be able to meet the procedure specification before applying it in practice.

In summary, welding the pipe joints is an integral and important part of pipeline construction. Advances in welding have improved weld quality, reduced weld repair rates and increased production rates. Although individual mechanized welding processes continue to improve (such as increasing the number of welding heads laying in welding material per pass), mechanized welding is generally accepted as BAT, especially for large-diameter transmission pipeline projects.

Emerging Technology

Pipeline operating companies are considering a range of emerging automated welding technologies to improve on what already exists or to replace traditional stick welding.

An emerging technology routinely used in the auto manufacturing industry is Hybrid Laser Arc Welding (HLAW). At present, the laser equipment is large and costly, and is more suitable for industrial applications. However, more cost-effective, smaller and more powerful lasers capable of use in pipeline construction are in development.[31] The American Society of Mechanical Engineers (ASME) is developing guidelines and standards to apply HLAW to pipeline welding, which will allow operating companies to use this technology.

Smaller-scale automated welding systems being developed in a workshop environment could increase welding quality and speed and improve data collection. The challenge is adapting these prototypes to weld large-diameter pipes in the field.

4.1.9 Girth Weld Coating

Pipe joints are treated externally in the **pipe mill** with a corrosion-resistant coating. However, a few centimetres of exterior surface are left uncoated at the ends to allow the field girth welds to be formed. Once they are complete, it is necessary to coat the weld and the unprotected ends around it with a corrosion-resistant layer before lowering the pipe into the ditch.

A number of protection schemes have been tried in the past, notably tape coating and shrink sleeves. Although these methods produce stable results for a period of time, long-term interaction with the soil that surrounds the buried pipes causes the corrosion-resistant material to disbond from the pipe.

The most robust current technology for large diameter pipeline construction to avoid this deterioration is to field-coat the girth weld areas with epoxy.

Girth Weld Coating Shack

4.1.10 Non-Destructive Evaluation (NDE): Radiography (X-ray), Ultrasonic (UT), and Coating Testing/Examination

A critical process to maintain the integrity of a pipeline is to ensure each girth weld that joins a pipe joint undergoes Non-destructive Evaluation (NDE). NDE detects flaws in the weld that could form a crack. In these direct assessment methods, physical access to the pipe is required to examine the exposed pipe for degradation from the surrounding soil environment or operational conditions.

Common methods include X-ray and ultrasound. Mounted on the pipe exterior, the equipment can provide a cross-sectional view of the completed weld. If a defect is found, it could be weld-repaired depending on the type of flaw. If it cannot be, the pipe weld will be cut out and a new weld performed.

Direct examination methods include:

- Radiographic (RT—including X-ray and Gamma-ray inspection);
- Ultrasound (ultrasonic examination or UT);

- Eddy current, or electromagnetic inspection to detect defects using eddy currents induced in the pipe by an alternating current electromagnet;
- Magnetic particle inspection, which induces a direct current magnetic field in the area of suspected cracks and attracts iron particles on the surface of the pipe, making cracks visible; and
- Liquid or dye penetrant, in which dye is attracted to, and highlights, cracks in the steel by capillary action.

Magnetic Particle Inspection

The pipe and girth weld coatings undergo tests and inspections to ensure no imperfections expose the pipe's steel surface. Electronic instruments known as **holiday detectors** find these imperfections, known as holidays. Repaired holidays are inspected again before lowering-in can proceed.

4.1.11 Lowering in and Backfilling

Once welded, coated, and inspected, the pipe string is lifted from the wooden skids and lowered into the **trench** with several side booms working in sync down the pipeline string. The process, which is largely gauged visually, must be carefully controlled to ensure the pipe is not overstressed while lifted and lowered. Individual pipe strings that have been lowered into the **trench** are then welded together. These welds are known as **tie-in** welds.

This basic process has not changed significantly in the last 50 years, however, using load cells (a type of sensor or a transducer that converts a load or force acting on it into an electronic signal that can be interpreted by the user) on the lifting equipment is becoming more common, which makes it less likely that the pipe being lifted and lowered into the **trench** will become over-stressed.

Lowering In

As lowering progresses, one last coating integrity check can be made with the **holiday detector**. This is another opportunity to detect any flaws in the coating that may have been missed or which were hidden from view underneath the pipe as it sat on supports. At this stage, if necessary, coating repairs can be made before laying the pipe in the **trench**.

Once the pipe is lowered into the open **trench** and tied in, the **trench** is **backfilled** with soil. Low impact techniques are available or under development to minimize the disruption from conventional trenching. In some cases, these techniques completely avoid the need for **backfilling**.[*]

4.1.12 Horizontal Drilling and Microtunneling

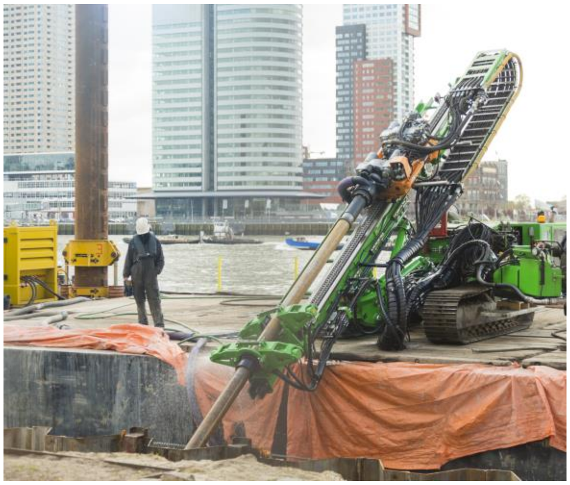
Operating companies use trenchless technologies where municipal, environmental, or space constraints prevent conventional trenching. Two of the more common trenchless techniques available are:

- **HDD**; and
- **microtunneling**

4.1.12.1 Horizontal Directional Drilling (HDD)

Instead of conventional trenching, a pipeline bore hole is drilled under a feature of concern. A pre-welded section of the pipeline is then pulled back into the bore hole.

HDD typically begins by drilling a pilot hole with a small-diameter **drilling string**. A drilling fluid helps break down the soil (using high pressure jets) and carries away the cuttings. The pilot hole is enlarged by successive passes of the drill pipe using larger heads (reamers) until the drill path is the necessary size. The **drilling string** can be steered along a predetermined path under challenging obstacles such as rivers, significant elevation changes or manmade utilities.



Horizontal Directional Drilling (HDD)

This approach can be used to traverse steep or unstable slopes. Some regulatory agencies have developed guidelines to use HDD to install a pipeline channel under sensitive environmental features that cannot otherwise be avoided (such as watercourses, wetlands, rare plant sites and archaeological features).[32]

HDD is becoming more cost effective with a higher certainty of success, resulting in increased use of this and other trenchless methods.

Geotechnical evaluations aid in selecting the most successful drill path, since HDD can fail when an unforeseen obstacle or soil condition is encountered that snags the drill or makes steering difficult.

HDD Challenges

Innovations in trenchless technology continue, but HDD does present some challenges. These challenges are listed as follows.

[*] We discuss these techniques later in section 4.2.4 (Soil Management) and section 4.2.5 (Low Impact Pipelining).

- ***Frac-out,*** a hazard in which the drilling fluid inadvertently releases into the soil creating an undesirable environmental impact.*
- ***Difficult soils,*** where granular soils such as sand and gravel make it difficult to maintain drilling fluid in the borehole used to take cuttings away from the drilling head. Also, granular soils make it difficult to maintain a clean hole because the soil sloughs in as drilling fluid dissipates into the pore spaces in the soil, creating a fluid environment. This issue has largely been resolved by combining HDD technology with auger **boring** technology in a new practice called **microtunneling**.

4.1.12.2 Auger Boring

This approach can be used for short crossings. Two methods are common: cradle and track. The main difference is how the **boring** machines are supported. In cradle **boring**, cradles slung from conventional pipeline side **booms** support the **boring** machine. In track **boring**, a track in the excavation supports the machine. In both, excavation is required on each side of the crossing. One side accommodates the **boring** machine. On the other side, the connection of the pipe is fed through the bored crossing to the rest of the buried pipeline.

Auger Boring

4.1.12.3 Microtunneling

Microtunneling is an emerging and maturing technology that can overcome many of the challenges of the other methods. It combines guided auger **boring** with the steering ability of HDD, which has enabled successful drilling in problem soils like sand.† **Microtunneling** is typically only used when HDD would be preferable but is not feasible.

4.1.13 Final Tie-ins (Including Specific Welding Procedures)

Once the individual **backfilled** test segments of the pipeline in the **trench** have been successfully hydro tested,‡ they must be welded together to form a complete pipeline segment. Depending on the terrain profile, these test sections can range from a few hundred metres in mountainous terrain to tens of kilometres on the prairies (see section 5, Commissioning). The **tie-in** welds are similar to the "girth welds" that join the individual joints

Tie-in Weld

* See section 4.2.1 (Eco-Friendly Materials).

† The solution lies in **microtunneling**'s ability to maintain the borehole by feeding the crossing pipe in behind the auger boring head continuously, as the hole is being tunneled. By preventing sloughing in of the soil and associated loss of soil strength at the cutting head, **microtunneling** generally achieves greater directional control than HDD. Additionally, overcut to reduce friction issues is minimal with **microtunneling**, and cuttings are transported internally back to the surface entry point, within the crossing pipe being microtunneled.

‡ See section 5.1 (Hydro Testing).

of pipe before they are lowered into the **trench**. However, the **tie-in** welds clearly cannot be subjected to the hydro test (since they now form part of the completed pipeline). That being the case, special attention has to be paid to making and examining these welds – including as with all girth welds, performing 100% radiography or UT inspection.

BAT is to make the tie-in welds carefully, with low-hydrogen electrodes, and examine them 360 degrees with UT or radiography 24 hours after the weld is completed to check for possible delayed cracking.

While **tie-in** welds are performed for new pipeline, a "cut in" weld is used for pre-tested pipe sections or assemblies that have to be welded to an existing pipeline (for example in repairs following a failure, or when inserting mainline valve assemblies). Unless the **tie-in** is to an existing valve, clearly the pipeline has to be emptied of product. Particular attention has to be paid to the welding process (especially in the case of oil pipelines) to avoid the possibility of igniting residual traces of product.

Note that as with all individual sub-segments that are tied in to form the pipe segment, in **HDD, microtunnelling,** and **auger boring**, the pipe string will be hydro tested and all of the girth welds radiographically or UT tested before the pipe string is installed and tied-in to the rest of the pipeline.

4.2 Pipeline Pre-Construction Planning and Construction: Environmental Considerations

4.2.1 Eco-Friendly Materials

Eco-friendly materials are alternative materials for pipeline and facility construction that present, or may present, less environmental concern than historical materials.

Examples of eco-friendly materials relevant to pipeline and facility construction are listed as follows.

- ***Biodegradable geotextile fabrics*** (e.g., coconut matting and coir wrap) to control **erosion,** instead of plastics or polypropylene fabrics. Biodegradable **geotextile** fabrics are an alternative to non-biodegradable materials whenever **geotextile** material is required.
- ***Reusable timber mats*** to create temporary construction access roads, usually through wetland areas instead of layered materials that have been hauled in to construct the road and then hauled out to reclaim road access.
- ***Geogrid roads*** for temporary access roads to minimize the volume of fuel used to haul **aggregate** (e.g., gravel) to site; they also reduce rutting.[33]
- ***Biodegradable or ecofriendly hydraulic fluids*** (e.g., vegetable-based or biodegradable fluids) in heavy equipment (e.g., dozers, excavators, HD drills) when working in and around water (e.g., **watercourse** crossings and wetlands).[34]
- ***Environmentally friendly drilling muds and systems*** for trenchless pipeline crossings at watercourses (typically bentonite-based drilling mud, remove cuttings and stabilize the hole). Aquatic habitats can be negatively affected by the release of bentonite-based

drilling mud. Careful monitoring of drilling operations and immediate responses to drilling mud releases (called frac-outs, see section 4.1.12.1) can minimize any negative effects of using bentonite-based drilling fluids.
- ***Geotextile pipeline weights*** instead of conventional concrete weights to control buoyancy. Additionally, screw piles can be used to anchor pipelines in high buoyancy areas.

4.2.2 Noise and Light Pollution

Noise Pollution

Pipeline construction activities generate noise during activities such as:
- preparing the site (e.g., clearing, grading, grubbing, **levelling**, blasting, crossing construction such as HDD, and **boring** under roads and watercourses);
- constructing the pipeline and pipeline facilities; and
- upgrading and building access roads.

Reducing Construction Noise

Equipment Strategies:
- fitting construction equipment with improved muffler systems;
- using electrically powered equipment;
- equipping exhaust vents with commercially available silencers;
- locating equipment to take advantage of natural shielding from terrain or other structures;
- orienting equipment to direct sound emissions away from **receptors** (e.g., humans and wildlife);
- erecting sound barriers around equipment or work areas to direct noise emissions away from **receptors**;
- timing restrictions during the work day; and
- moving equipment further away from **receptors.**

Policies and Practices:
- implementing equipment and vehicle idle reduction policies;
- using noise absorbent material on barriers to reduce sound emissions from work areas and specific equipment;
- minimizing the need for reversing alarms by designing the site layout to avoid reversing, such as a drive-through for parking and deliveries;
- responding promptly to complaints to minimize public dissatisfaction; and
- reducing the hours of operations during the nighttime periods and weekends.[35]

Emerging technology for noise includes***:***
- alternatives to the typical “beeper” alarms (for example, smart alarms that are adjustable to the **ambient** level of noise, and broadband backup alarms with no tonality—meaning the sound is still audible locally but less jarring and travels only a short distance);
- noise monitoring stations with web-based connectivity to provide real time information—such as noise level, audio recording and text messaging—if a specific sound level is exceeded.

Light Pollution
Construction equipment accounts for much of the light pollution tied to pipeline and facility construction. BAT to mitigate such light pollution focuses largely on site-design planning to achieve targets such as:

- installing full horizontal light fixtures to control light spill;
- locating parking and fueling stations so that headlights are not directed towards **receptors** (e.g., nearby residences) and key wildlife areas; and
- leaving standing vegetation in place when possible to block light from construction traffic.

Emerging technology for light pollution includes:

- energy efficient light-emitting diode (LED) lights that produce warm-toned lighting, which is less disruptive to animals and humans; and
- motion-activated lights at facilities to reduce disturbance when light is not required.

4.2.3 Construction Timing

Managing timing for construction activities helps manage environmental considerations. These include:

- times to avoid;
- scheduling **restricted activity periods (RAPs)**; and
- alternatives when restricted activities guidelines cannot be met.

Construction typically should not occur when soils are unable to support machinery without risk of compaction or rutting (e.g., when agricultural soils are too wet, or when wetlands are not frozen).

Operating companies also avoid construction during RAPs for vegetation, wildlife, and aquatic species. [20,21, 36,37] Some of these RAPs are enacted in law and protect vulnerable species, and some are enforceable conditions of project approval. Other RAPs are guidelines designed to help pipeline companies comply with provincial and federal acts, regulations, and related polices that protect a variety of environmental resources.

It is best to construct pipelines and associated facilities when the potential for environmental effects are lower, which is region- and project-specific. For example, fall and early winter may be best on native prairie since:

- native vegetation is dormant;
- soils are suitably dry or frozen; and
- RAPs for migratory birds and other wildlife species of concern are not in effect.

4.2.3.3 Construction Mitigation for Restricted Activity Periods

Restricted activity periods (RAPs) and other environmental timing considerations are routinely built into overall project schedules, alongside commercial, constructability and other factors. Environmental **timing windows** frequently inform construction schedule decisions. The Canadian Energy Pipeline Association (CEPA) has published draft best practices for migratory birds and the pipeline industry. These include measures for when **timing windows** cannot be met,[38] such as conducting nest surveys, defining local **set-backs**,[38] and pre-clearing sections of the ROW to discourage nesting. The Canadian Association of Petroleum Producers (CAPP) has recently produced a set of best practices to assist exploration and production companies.[39] Construction timing is critical to consider for construction in woodland caribou habitat.*

4.2.3.4 Documentation to Communicate Environmental Timing Windows

To communicate environmental **timing windows** to contractors, or when alternate **mitigation** may be necessary, the operating company uses the following documents from the appropriate parties (e.g., Environment and Climate Change Canada, Fisheries and Oceans Canada):

- Environmental Alignment Sheets (EAS);
- the associated project **Environmental Protection Plans** (EPP); and
- site-specific construction and reclamation plans.

Traditionally, these documents were on paper, with infrequent updates. Today, they are usually digital, and are regularly updated throughout the construction season. This practice ensures the most appropriate **mitigation—**during the right timeframe and at the correct locations.

Emerging Technology

Emerging technology for RAPs includes tablet-based field recording and submitting real-time, daily nest survey and denning information via GIS. Construction contractors can use this information to plan their daily schedules. Many systems now link GIS data on environmental restrictions directly with Global Positioning System (GPS)-enabled construction equipment to help ensure that construction activities do not occur inside RAPs. Exceptions include pre-construction environmental surveys that clear the company to construct in the area, or alternative **mitigation,** in place to protect the resource.

Thermal imaging cameras are increasingly identifying den or nest occupancy before construction. These cameras use infrared radiation to look through vegetation or snow cover into den and nest sites. Advancements in the camera technology and image quality represent areas of emerging technology.

4.2.4 Soil Management

Appropriate soil handling throughout pipeline and facility construction is critical to minimize adverse effects to soil productivity. The pipeline industry uses a long-established set of soil management practices to strip, store and replace surface soils. [20,36,40,41] These practices establish EPPs, developed as part of regulatory applications for pipelines and facilities.

4.2.4.1 Soil Handling

BAT for soil handling are typically built into the EPP (or associated contingency plans, as appropriate) for the soils along the ROW. These measures may include:

- avoiding or limiting soil handling;

---

* See section 2.2.1.5 (Caribou Habitat Protection and Restoration) for a discussion of management approaches for caribou, including relevant, existing and emerging technologies. Fisheries **timing windows** are similarly discussed in section 4.2.7 (**Watercourse** Crossings).

- using specialized equipment (e.g., narrow trenching buckets, **wheel trenchers** and low ground pressure equipment) during unsuitable weather conditions, such as high rainfall periods, snow melt and extreme drought;
- using **geotextile erosion** control blankets that cover exposed soils;
- using chemical **tackifiers** that effectively create a sticky top layer on exposed soils; and
- using **straw crimping** to stabilize disturbed areas or spoil piles and reduce wind **erosion** risk (**erosion** and **sediment** control are discussed below).

The following **backfilling** practices are suggested as to prevent excessive **subsidence** or **erosion** of the backfill and support material: [42,43,44,45,46,47,48,49]

- investigating soil characteristics along the pipeline route during project planning and identifying soils that do not meet the specifications for **backfilling**,
- completing **backfilling** with local native material as soon as possible after pipeline installation to avoid water in the **trench**;
- If suitable, replacing segregated **soil horizons** in reverse order from excavation in appropriate lift thickness and **compaction** densities;
- using approved earth fill or sand padding over the pipe where local material is too rocky and may damage the pipe or pipe coating;
- **backfilling** by bucket placement, rather than by blading in material;
- **dewatering** flooded trenches before **backfilling**;
- monitoring and maintaining **compaction** records;
- applying topsoil over the **backfilled** spoil to facilitate revegetation;
- grading the surface of the **trench** to a crown, to prevent water ponding on the **trench** and to mitigate against minor **subsidence** and settlement; and
- providing crown breaks where necessary to maintain drainage conditions.

A number of the other environmental practices in this section, such as **low impact pipelining** techniques,[*] include measures that will reduce the amount of soils that must be handled and managed. They suggest how to avoid areas of specific concern, like those at risk from wind and water **erosion**, such as steep slopes or areas near **watercourses**.

4.2.4.2 Erosion and Sediment Control

Activities that disturb the ground around pipelines and facilities, including new construction and construction for maintenance operations, will expose soils to potential **erosion**. Wind and water can erode exposed soil and can release **silt** and **sediment** into sensitive features such as **watercourses** and wetlands, potentially harming fish habitat, aquatic species and vegetation. In addition, topsoil can erode due to wind action thereby potentially reducing the productivity of the soils. During the design phase, a sediment and erosion control plan (SECP) will be developed for the project, and may include additional requirements for selected sites.

[*] See section 4.2.5 (Low Impact Pipelining).

4.2.4.3 Typical Sediment and Erosion Control Measures

Environmental BAT for pipeline construction are included in the following list. [50,51,52]

- ***Sediment barriers*** (**silt fence**, fiber logs, geo logs) designed to remove **silt** from surface runoff during rain/storm events. They are placed at the boundary of work areas.
- ***Interceptor dikes/slope breakers*** (compacted soil, fiber logs, geo logs) installed to divert storm water off the ROW and into areas of undisturbed vegetation. They also prevent runoff reaching velocities that will cause exposed soils to erode.
- ***Dewatering*** (from trenches and ROW) by pumping water from the **trench** and/or ROW through filtration devices, such as filter bags or **sediment basins**, in areas of undisturbed vegetation. This will minimize **silt** and **sediment** released into adjacent features.
- ***Diversion ditches*** (similar to **interceptor dikes**) to divert water to vegetated areas or natural surface drainage features, such as swales or ditches. They also slow water velocities to minimize **erosion** during rain events.
- ***Non-vegetative soil stabilization*** (e.g., rolled **erosion control blankets**, netting, stone coverage) and temporary measures installed following construction cleanup, or if soil is exposed for more than 30 days. This will prevent soil **erosion** when insufficient vegetation is established to prevent **silt** and **sediment** release.
- ***Temporary seeding with nurse crop species***, such as annual rye or oats, when soil will be exposed for longer timeframes (i.e., soil stockpiled for more than 30 days).
- ***Permanent restoration measures,*** including seeding with native seeds, along with **nurse crops** consisting of annual rye or oats.
- ***Geotextile fencing*** consisting of non-woven material backed by wire mesh. This allows water to flow through fencing while removing some **silt** and **sediment**.
- ***Sediment logs*** consisting of wood or mulch material surrounded by a **polymer** mesh that allows water to flow through a three-dimensional filtering material. This limits overwhelming of **sediment** control often seen with woven **silt** fencing. Logs are also used on steep slopes to slow water velocities during rain events and prevent **erosion**.
- ***Hydro mulching or bonded fiber matrix*** are materials blown onto exposed soils. They contain materials such as mulch or **soil amendments** with seeds mixed into the mulch, which stabilize soil while vegetation establishes.

Qualifications

Best practice recommends that a qualified person inspect **erosion** and **sediment** control measures. Qualifications emerging in Canada include Certified Inspector of Sediment and Erosion Control (CISEC) and Certified Professional in Erosion and Sediment Control (CPESC).[53]

Emerging Technology

- Minimizing impacts during pipeline construction, the Innovative Pipeline Strategies project[54]—part of the Evergreen Centre for Resource Excellence and Innovation[55]—is conducting research and development in low impact soil handling. Its work has focused on testing new excavation methods, soil salvage equipment, **compaction wheels** and **finishing blades**.

- To reduce **sediment** released from construction sites, **polymers** applied directly to exposed soils have proven effective, and they have also been used in **flocculation** of **turbid** water released from construction sites. [56]
- To document inspections and revisions to **sediment** and **erosion** control, web-based construction inspection tools are now being used. These tools can include SECPs, inspection reports, photographs and approved revisions to the plans. The pipeline company, environmental inspectors, engineers, contractors and regulatory bodies can access the documentation. This promotes transparency between project personnel and other stakeholders.[53] The tools also facilitate information transfer during the construction phase, during operation of the pipeline and associated facilities, and when a**bandonment** is being conducted.

4.2.5 Low Impact Pipelining

Low impact pipelining reduces the intensity of disturbance to terrestrial resources such as agricultural and forested land, native vegetation and wildlife habitat. Environmental effects may be minimized by controlling:

- soil disturbance and material handling;
- vegetation clearing;
- **root mat** disturbance; and
- soil **compaction.**

Low impact methods are common in sensitive locations that are difficult to **reclaim** or **revegetate**, such as wetlands and native prairie. However, they may also be warranted or feasible for longer distances or entire projects.

4.2.5.1 Low Impact Practices

Low impact practices include:

- choosing minimal access development, which entails
  - using existing trails with minimal grading; or
  - driving on native vegetation when conditions make this suitable;
- using low ground pressure clearing and construction equipment;
- minimizing ROW width;
- using physical barriers such as **rig mats**/**swamp mats** to reduce disturbance to vegetation and soils;
- reducing **stripping** width to trench-line or **ditch and spoil** only;
- using specialized equipment such as topsoil cutters during soil **stripping** on frozen ground to minimize admixing;
- avoiding disturbance of the **root mat** during clearing of forested areas, and allowing trees and shrubs to recolonize the ROW after construction (these techniques are often termed Minimal Surface Disturbance or MSD);[57] and
- using trenchless technologies, such as HDD and **microtunneling**, which are low impact pipeline techniques that have been used extensively for **watercourse** crossings (section 4.1.12, Horizontal Drilling and Microtunneling, for a description of these techniques).

4.2.6 Acid Rock Management

Shallow **bedrock** and **bedrock** outcrops may be disturbed during pipeline construction activities, including surface clearing, trenching and blasting.[58] In certain natural conditions, **acid rock drainage** and metal **leaching** can result when freshly exposed or excavated rock containing sulphide minerals comes into contact with air and water. The resulting run-off can be toxic to aquatic and terrestrial organisms.[4,58]

During pre-construction planning, rock excavation areas that may create **acid rock drainage** can be identified through existing information or field sampling programs.[4,59,60] Typical acid rock drainage **mitigation** measures include avoidance, covering exposed acid rock with non-acid generating rock material, blending acid rock with neutralizing materials, diverting water, and collecting and treating acid drainage. [4,59]

An effective but infrequently used **mitigation** process is **subaqueous** (underwater) disposal: [4] moving rock with acidic properties from construction sites to water bodies where they will not be exposed to air. This strategy works in both fresh and ocean water, and stops **acid rock drainage** by preventing oxidation of sulphide minerals and associated metal **leaching**.

4.2.7 Watercourse Crossings

Watercourse crossing design must consider several factors, such as engineering standards, **geotechnical** data, expected stream flows and integration of environmental considerations. This may include fish and fish habitat, vegetation and wildlife habitat.[61] An overview of the methods and typical mitigation measures for installing pipelines under watercourses can be found in the regulator and industry endorsed publication, Pipeline Associated Watercourse Crossings guidance document[*].

The main methods for installing pipelines across watercourses are:

- below-ground **trenchless crossing**;
- aerial or above-ground crossing;
- isolated **trench** crossing; and
- instream **trench** crossings.

4.2.7.1 Below-Ground Trenchless Crossing

To avoid activities within the **watercourse**, below-ground trenchless pipeline crossing methods (e.g., HDD, **microtunneling**, direct tunneling, **punching** and **boring** – see Section 4.1.12) are BAT; however, **geotechnical** investigation of below-ground conditions is necessary to determine the feasibility of these methods.

- ***HDD*** can be used at longer **watercourse** crossings (length depends on size of pipe, crossing location conditions and other variables) up to approximately four kilometres, although larger pipe diameters reduce this distance.

[*] See Pipeline Associated Watercourse Crossings, Fourth Edition (2012)[42]

- ***Microtunneling*** can be used over shorter distances—depending on method, pipe diameter and local ground conditions.
- ***Direct tunneling*** uses less drilling fluid and operates at lower pressures than HDD or **microtunneling** techniques, and can reduce the risk of unplanned releases of drilling fluid.
- ***Horizontal punching and boring techniques*** operate without using pressurized drilling fluids, and so avoid any unplanned releases. However, they often involve increased surface disturbance compared with other methods.

Water quality monitoring for drilling fluid release is conducted during trenchless crossings. Automated instream remote monitors with alarm systems can be used to warn and potentially shut down drilling operations.

4.2.7.2 Above-Ground Pipeline Crossings

Also known as aerial crossings, above-ground pipeline crossings can be constructed with no instream footprint (otherwise called **clear-span**) at shorter crossings. Aerial pipeline crossings can also be constructed underneath or alongside bridge structures to take advantage of existing or new **infrastructure**.

Above-Ground Pipeline Crossing

4.2.7.3 Isolated Trench Crossing

Trenched pipeline crossing techniques are preferred when a **watercourse** is dry or frozen to the channel bed. However, isolated **trench** crossing methods, such as a **dam and pump,** or a **flume**, can also be used:

- at smaller **watercourse** crossings;
- where trenchless methods are not feasible (e.g., subsurface **bedrock**); and
- where there is a high risk of unplanned releases of drilling fluid (e.g., porous or unconsolidated subsurface).

Isolation methods effectively prevent or minimize **watercourse** sedimentation based on channel and water-flow characteristics. Downstream flow is maintained with a **flume** or a **dam and pump**. Fish within the isolated section of the **watercourse** can be rescued from the isolation structure and released downstream. The top layer of **channel substrate** is removed, stored separately, and returned to channel pre-construction conditions. Alternatively, clean rock can be trucked in. The channel bed and banks are restored to their original contour and gradient, and banks and vegetation areas are

Isolated Trench Crossing

stabilized and **revegetated**.

Stabilizing and revegetating can involve bioengineering with natural locally sourced materials, such as tree revetments, living crib wall, natural soil wraps, plant cuttings, and so on. Vegetation can also be removed in a way that maintains root masses to stabilize banks and enhance revegetation after the crossing is constructed. Non-isolated **trench** crossing techniques tend to be the least-preferred crossing option for a flowing stream. They are typical when no other crossing technique is feasible, or as a contingency option if the preferred method fails.

4.2.7.4 Instream Works

Instream works are avoided wherever possible, but mitigated if unavoidable.[62] Descriptions of BAT for **watercourse** crossings for pipelines and temporary crossings are provided in the Pipeline Associated Watercourse Crossings guidance document.[42,63]

Site-specific watercourse crossing plans
During the design phase of the Project, site-specific watercourse crossing plans may be developed for sensitive watercourses, and will consider how to:

- minimize the duration of instream activities;
- abide by instream timing restrictions (i.e., avoid seasonal high risk periods within lifecycles of resident aquatic organisms);
- maintain clean water flow and, where possible, eliminate **sediment** or suspended solid release into the **watercourse**;
- minimize disturbance of the **watercourse** bed and banks;
- minimize **erosion** of the **watercourse** bed and banks;
- use **sediment** control measures where warranted; and
- maintain downstream flow.

Site-specific watercourse crossing plans include how to:

- restore **riparian** areas and crossing approaches to prevent or minimize **sediment** release into **watercourses**;
- ensure that no materials that could cause harm (e.g., **sediment**, fuel) are deposited to any **watercourse**;
- ensure **offsetting** is implemented when harmful effects cannot be avoided or mitigated;
- conduct post-construction monitoring on a multiple-year program to assess the success of **mitigation** and reclamation measures and/or **offsetting** measures; and
- document opportunities to improve procedures and specifications. [42]

Site specific watercourse crossing plans also consider depth of cover. **Depth of cover (**the vertical distance from the top of a buried pipe to the surface) is important to consider in **trenched watercourse crossings**. The two common approaches to specify the minimum depth from the channel bed for a **watercourse** crossing are:

- a conservative crossing depth, based on the minimum **depth of cover** required by
    - industry standards (e.g., CSA Z662),
    - operating company standards and guidelines (e.g., [43, 44]), and/or
    - regulatory criteria developed by local regulatory agencies; and

- individually assess the erosive, downgrading and lateral movement potential of a watercourse to determine long term loss of cover potential to subsequently inform pipeline crossing design[*] [64, 65]

The upcoming fifth edition of the Pipeline Associated Watercourse Crossings guidance document contains a fisheries self-assessment tool. This tool is based on the *Fisheries Act* and helps to assess the likelihood that pipeline and associated temporary vehicle **watercourse** crossings could cause serious harm to fish. The tool helps pipeline companies to meet the legal obligations of the SARA, as it relates to aquatic species.

4.2.8 Invasive Species Management

Activities that disturb the ground around pipelines and facilities can spread **invasive species**, including weeds and soil pathogens.

4.2.8.1 Reducing the risk of spreading invasive species

To reduce the risk of spreading **invasive species**, the following best practices are recommended:[66,67]

Planning

- Identifying and documenting areas with **invasive species** through pre-construction surveys and by consulting landowners.
- Developing mitigation and treatment plans to reduce the spread during construction, and infestation during operation of the pipeline and associated facilities.
- Developing an appropriate **sediment** and **erosion** control plan to limit erosion of soil and seeds from the site.
- Educating operations and construction staff about the risks of **invasive species**, including how to identify them.

Procedures

- Implementing an equipment cleaning protocol so that equipment is washed before moving from an infested site to a non-infested site. Equipment cleaning will reduce the risk of spreading **invasive species**, and will also reduce transfer of soil-borne diseases, such as clubroot and soybean cyst nematode. The Clean Equipment Protocol for Industry[68] contains relevant protocols and checklists.
- Limiting disturbance that could create conditions favourable to **invasive species** becoming established.
- Maintaining soil/spoil piles within the work area boundaries, especially when **invasive species** are present within the work area and not in surrounding areas.
- Revegetating disturbed areas as quickly as possible to prevent aggressive **invasive species** establishing and outcompeting native species. A fast-growing **nurse crop**, such as annual rye or oats, will minimize **invasive species** growth and prevent **erosion** at the same time. [66,67]

---

[*] This can be assessed using methods developed by Lacey (1931) and Blench (1970), with relationships developed by Pemberton and Lara (1984), described in the USDA (United States Department of Agriculture) 2007. National Engineering Handbook. Part 654 – Stream Restoration Design.

- Using certified seed suppliers to minimize the potential for **invasive species**' seeds to be present in seed mixtures.
- Obtaining **aggregate** supplies from weed-free sources.
- Ensuring every piece of equipment used to construct the project is cleaned of weed seeds prior to entering the work site.
- For sensitive sites, such as organic farms, cleaning every piece of equipment prior to entering the property.
- Educating operations and construction staff about the risks of **invasive species**, including how to identify them.

Examples of Problematic Species

Clubroot (Plasmodiophora Brassicae)

This plant presents some unique management challenges, as it is easily spread by contaminated agricultural and construction equipment and wind-borne transfer. Clubroot is difficult to eradicate once a field is infected and no effective chemical controls exist. Clubroot management plans that establish protocols for equipment cleaning in clubroot-infected areas guide pipeline construction and operation. There is a growing body of clubroot research and technology available from various sources, including the Canola Council of Canada's website.[*]

Zebra Mussel (Dreissena Polymorpha)

This animal is an example of an invasive freshwater species that causes a variety of environmental and other concerns in areas that it colonizes. For example, zebra mussel can displace native species, clog pipelines, disrupt water treatment plants and spread diseases such as botulism. [69,70] Zebra mussels may be spread by contaminated **watercourse** crossing construction and maintenance equipment. Withdrawing and releasing water for **hydrostatic testing** can also transfer zebra mussels (or other species) between **watersheds**. It is one reason why transfer of **hydrostatic** test water between **watersheds** is usually not permitted. Thoroughly cleaning and drying equipment before moving it to new locations reduces the risk of transferring zebra mussels or other aquatic **invasive species** to new locations.

Emerging Technology

Emerging technologies for managing **invasive species** on pipeline ROWs include handheld devices such as smartphones, tablets and GPS units with which an operating company can identify and record the locations of **invasive species**, save the locations to an online mapping tool, and indicate:

- the preferred sites for equipment cleaning stations;
- locations to obtain clean aggregate and soil material; and
- revegetation and weed management areas of concern.

Such information, provided in field-accessible digital formats that are easy to update, makes it much easier for construction contractors to avoid areas with **invasive species** and to implement **mitigation** where required.

[*] See www.clubroot.ca

4.2.9 Protecting Indigenous Traditional Use of Lands and Resources

The regulatory requirements and guidance on the environmental consideration of traditional use (TU) and traditional ecological knowledge (TEK) in pipeline planning and construction are largely found in the NEB Filing Manual. Federal and provincial guidelines direct that Indigenous traditional knowledge be considered in different aspects of the pipeline project, particularly regulatory applications and project planning. [71,72,73] Practices and procedures for addressing TU and TEK are largely developed project-by-project, and often appear as approval conditions or corporate policy rather than a standardized code of practice.

BAT and emerging technologies that mitigate environmental effects on traditionally used resources in other disciplines—such as wildlife, vegetation, aquatics, historical resources, acoustic environment, and atmospheric environment— would apply in this domain, as would the ecosystems that support them.

Several current practices that can be considered BAT for the protection of TU include:

Engagement (Early and Throughout the Project) With Indigenous Groups to:

- identify site-specific traditional use areas and locations during detailed routing;
- develop measures that eliminate or minimize effects on access and quality and quantity of traditional resources, especially during key periods of use;
- obtain input about construction timing and the planning process;
- engage Indigenous cultural monitors from potentially affected Indigenous groups to identify and implement **mitigation** for traditional use interests that may be affected during construction;
- provide an opportunity to hold a ceremony or cultural observance before disturbance, if the Indigenous group deems it appropriate; and
- provide compensation for Indigenous trappers' and harvesters' trapping and harvesting losses.

Other Strategies:

- engage more broadly with Indigenous groups to develop TU and TEK study programs that gather meaningful material to incorporate into project planning and the regulatory process;
- collaborate with potentially affected Indigenous people;
- include traditional land and resource use as a valued component to consider in ESA;
- identify opportunities for pre-disturbance harvesting of traditionally used resources;
- implement **mitigations** to reduce environmental effects to traditionally used resources and the ecosystems that support them;
- implement minimal surface disturbance techniques to reduce impact on traditionally used plants; and
- follow-up with post-construction monitoring to determine effects on viability.

Emerging technology and practices include:

- developing native plant nurseries;
- training in collecting seed and replanting local vegetative species; [74]
- using native species for reclamation;
- advancements in the replanting of medicinal plants or other important vegetation in the area;
- including TU and TEK in land reclamation planning; [74]
- undertaking habitat **offsetting** for affected important wildlife;
- consulting with Indigenous groups to develop Indigenous reclamation standards; [74]
- creating a project advisory committee with Indigenous groups to facilitate more effective information exchange; [74] and
- clearly communicating to potentially affected Indigenous groups how TU and TEK information has been considered and incorporated into project planning and the regulatory process. [75]

4.2.10 Reduction of Construction-Related Greenhouse Gas and Methane Emissions

GHG emissions from pipeline and facility construction largely come from construction equipment emissions. BAT to reduce construction-related GHGs during construction is to select energy efficient construction equipment. [25]

Planning principles and mitigation measures can collectively reduce project-related air contaminants and GHGs released into the atmosphere during construction.[*] Several of these include:

- using well maintained, modern equipment with the lowest available emissions ratings;
- using electrically driven or alternative fuel equipment;
- minimizing idling or operating time;
- using locally available equipment;
- minimizing the number of vehicles required to transport people and equipment, and the distances travelled (e.g., using multi-passenger vehicles, locating camps in proximity to the work site); and
- planning ahead to minimize the number of haul routes required for construction materials.

New technologies that reduce equipment energy requirements can further reduce construction-related emissions and include: low-energy lighting systems and energy efficient accommodations and supporting **infrastructure**.

Tracking and offsetting GHG emissions is a relatively new approach in the pipeline sector, and may be required as a regulatory condition. The following types of information, for example, could be required for verifiable offsetting of pipeline construction-related GHG emissions:

- a description of the offset options and the criteria against which they are assessed;
- the magnitude of the proposed offset;
- confirmation that the offset may be registered with a third-party verification body; and
- verifiable accounting, confirming that no net increase in GHGs occurred during the construction phase. [76]

4.2.11 ROW Reclamation

Reclamation is the final stage of the pipeline construction process. It involves restoring the ROW to pre-development land use capability through practices and techniques, and considers facilities sites.

4.2.11.1 Reclamation Practices

Reclamation practices may include:

- replacing salvaged topsoil;
- re-contouring;
- restoring surface drainage patterns and revegetation; and

[*] Information on emission management that occurs during the operation stage can be found in section 6.2.9 (Air Emissions Management).

- implementing measures to address any effects of construction on soil capability, such as **compaction**, admixing and excess stoniness.

Ongoing monitoring and maintenance of the reclaimed ROW is necessary to confirm its success. This means meeting regulatory approval conditions and landowner expectations (e.g., weeds are properly controlled, **trench** has not subsided).

Reclamation practices vary by jurisdiction, biogeographic region, vegetation type and existing land use. For example, revegetation of agricultural land relies mostly on creating suitable conditions on the reclaimed ROW for crop growth. Reclamation of native vegetation areas requires a wider range of processes from seeding and planting to allowing natural regeneration to proceed. Reclamation may also include measures to maintain or enhance wildlife habitat.[*]

4.2.11.2 Reclamation Techniques

Numerous techniques may be applied during pipeline ROW reclamation that depend on the location and end land use. These include:

- revegetating immediately after construction so that sufficient growth can manage **erosion** concerns within one growing season. Operating companies may also consider seeding **erosion**-prone areas with an annual cover crop to immediately protect from **erosion**;
- using standard agricultural equipment on agricultural land, such as **rippers**, **harrows** and **subsoil ploughs** to mitigate excess surface **compaction**, admixing and stoniness;
- using specialized clean-up buckets on backhoes to avoid **scalping** native grassland; and
- rolling back cleared woody vegetation in forested areas to reduce the risk of **erosion** and sedimentation, particularly in proximity to **watercourse** crossings.

4.2.11.3 Facilities Reclamation

Facilities are typically maintained as fenced, graveled and non-vegetated sites because of operational and safety requirements. Facility reclamation typically involves securing the stability of the site during the operating phase, and also maintaining soil stockpiles on site to use during final reclamation after the facility has been decommissioned. Stockpile maintenance measures include **erosion** control, surface water management and weed control.

Emerging Technology

Reclamation is an area of ongoing and active research and monitoring. Emerging technology for establishing rapid vegetation are described in the following list.

- ***Using engineered soil***, where a mulch/**soil matrix** is mixed with a seed mixture and sprayed onto exposed soils. The mulch/**soil matrix** provides **erosion** control and nutrients that will promote rapid establishment of vegetation following construction; and
- ***Greenhouse-grown fescue plugs*** for an ecologically sensitive plant community (e.g., foothills rough **fescue** grassland) that is difficult to **revegetate** through seeding or natural regeneration. These plugs have been tested with some success on abandoned well-sites, and could be used as part of a revegetation strategy on pipeline ROWs that cannot avoid traversing rough **fescue** communities.[77]

---

[*] See section 2.2.1.5 (Caribou Habitat Protection and Restoration).

5.0 COMMISSIONING

Commissioning of the pipeline takes place after construction. It is the final detailed testing and inspection of the pipe integrity necessary to deem the pipe suitable for operation. The following sections describe BAT and emerging technology related to the commissioning phase.

5.1 Hydro Testing

Pipe and pipe components are pressure tested before being put into service. This testing can involve various substances: a gas, such as dry air; the product to be transported, such as oil or gas; or water. Since water is the most common testing substance, this pressure test is known as a hydro test.

5.1.1 Procedure

1. To test for both strength and leaks, a pipeline is filled with water and pressurized to a level that exceeds maximum operation pressure. This will reveal any defects in the pipeline or the welds at pipeline joints.[78]
2. To validate the strength of the pipe, it is subjected to a pressure from 125% to 150% of its intended maximum operating pressure (depending on location), and held for a prescribed period of time (typically four hours).[*]
3. To check for leaks, the pressure is then lowered to 110% of the maximum operating pressure and again held for a prescribed period of time (again typically four hours). Should failures occur in either test, the pipe is repaired and the test re-run.

5.1.2 Environmental Protection Measures for Water Withdrawal and Disposal

Hydrostatic testing depends on drawing temporary water withdrawals from natural water bodies where a sufficient volume of water remains to support aquatic ecosystems. While water volumes required for pipeline construction and **hydrostatic testing** are temporary in nature, and ecological flow requirements in source water bodies are a significant consideration during design, pre-construction planning and regulatory requirements. Once testing of the pipeline integrity is completed, the water will be released according to regulatory requirements.

Water Withdrawal

Different methods determine ecological flow requirements, including hydrological, hydraulic rating, and habitat simulation.[79] Existing methods differ drastically in scope and implementation costs, [79] making appropriate scoping important. For instance, for rivers with natural flows where site-specific information is not available, a conservative desk-top method to calculate the flow requirements has been developed in Alberta.[80]

Typically, water withdrawal rates in environmental permits issued for a project by the Provincial regulator will require a maximum withdrawal rate is 10% of flow. Provincial regulatory bodies provide guidance related to volumes, often require registration of water withdrawals, and often request data related to the hydrological information discussed above.[81] Screens on intake pumps must be appropriately sized to avoid fish impingement and mortality as required by regulation.

[*] As specified in CSA Z662-15.

Water Disposal

Prior to the release of hydrostatic test water, required environmental considerations include: [82,83]

- testing of the chemical properties of water at the source and after **hydrostatic test** use at the discharge point;
- appropriate soil **erosion** control at the discharge location on land or into a **watercourse**; and
- avoidance of inter-basin water transfers to prevent unwanted transfer of **invasive species**.[84]

Emerging Technology

The commissioning hydro test has been part of pipeline construction since the 1950s. Its purpose is to demonstrate the pipeline's pressure containment capacity and soundness when operating at maximum pressure. Improved performance due to advances in steel making, pipe manufacture, welding and pipe handling have led to the concept of an alternative approach to demonstrating pipeline reliability through the application of an **AIV** that is equivalent to **hydrostatic testing**.

Water Testing

The AIV process is an emerging technology based on explicitly integrating and documenting the quality assurance and quality control (QA/QC) procedures for design, pipe manufacture and transportation, construction and commissioning.* Key elements of the process are:

- a third party that is completely independent of the operating company and construction contractor must oversee the entire process; and
- comprehensive, post installation leak detection.

The AIV process is based on a focused audit of the company's management system comprising the following key elements:

- management commitment;
- procedures and processes;
- QA/QC;
- communication and planning;
- monitoring and assessment (including process review, analysis, improvements, and corrective actions as required);
- risk management;
- management of change (MOC);
- documentation management;
- training and qualifications; and

---

* In British Columbia, regional information on water availability is provided by provincial tools, including the NorthEast Water Tool and the Omenica Water Tool. The tools are based on regional downscaling of hydrometric data, derived from 30-year average conditions.

- demonstrated implementation of the management system throughout the design, manufacturing, transportation, construction, and commissioning processes.

The environmental protection advantages of a successful AIV implementation over hydro testing include:

- elimination of water management issues (including water withdrawal, contamination, and disposal); and
- ability to implement in very cold conditions without the need for the chemical anti-freezing agents that could potentially be accidentally released into the environment.

Several major pipeline companies continue to refine and promote AIV, which is complex and difficult to demonstrably implement. Therefore, it is generally only applied in a partial and controlled implementation mode where consequences of an in-service failure are low, and external loadings are also low and can confidently be predicted.

5.2 Cleaning and Drying

After the pipeline has successfully passed strength and leak testing, the test water is drained from the pipe and the interior of the pipe is dried and cleaned.

Drying is achieved by passing a drying agent, such as methanol, through the line to absorb residual water that may remain at low points in the line.

Before it is put into service, ***cleaning*** pigs are passed through it to remove any debris that may have entered the pipe during construction and manufacturing. Bullet-shaped, polyurethane-coated foam "pigs" with imbedded wire brushes are one type of pig that is used to perform this task.

With the pipe cleared, a gauging pig is sent through the pipe to determine if the pipe has been affected by the **backfill** process (e.g., the cross section of the pipe deformed or the pipe dented during **backfilling**). This will help ensure that any such defects are remediated and that in-line inspection tools can subsequently pass through the pipeline without getting stuck. Specific provisions pertaining to the cleaning and drying of pipe can be found in the NEB OPR.[*]

5.3 Baseline Inline Inspection

The tools bolded and described below to assess pipe condition and detect possible damage are covered extensively in the next section, section 6.1.1 (Condition Monitoring).

The use of **high-resolution caliper tools** in addition to running a gauge plate pig (gauging pig) represents the BAT for detecting possible damage during lowering in and **backfilling**.

[*] NEB Onshore Pipeline Regulations (OPR)

Inertial mapping unit technology can determine the profile of the pipeline at the time of inspection. If a subsequent inspection is carried out a few years later, changes in the profile can be detected. The changes in profile can be readily understood by converting strains imposed in the pipeline over this timeframe from such **geotechnical** loads as slope movement, settlement, or **frost heave**.

Performing an early, baseline inspection is the best way to make use of this technology, since it provides a measure of the initial as-installed profile of the pipeline.

Intelligent Pig (MFL and Caliper)

6.0 OPERATION

Construction and operation phases have overlapping engineering and environmental considerations. However, the longer-term effects of operating a pipeline or facility may require a different combination of BAT than the temporary impacts of construction. These differences may also stimulate new technology in different ways. Section 6 (Operation) provides examples of engineering and environmental BAT and emerging technologies for the operation phase.

6.1 Operation: Engineering Considerations

6.1.1 Condition Monitoring

Operating companies monitor the condition of a pipeline. The following identifies BAT for the practices:

- inline inspection;
- in-service hydro testing;
- direct assessment; and
- leak detection.

6.1.1.1 Inline Inspection (ILI)

Operating companies use ILI to detect anomalies on the internal and external pipe surfaces. The ILI tool runs inside the pipeline and are often referred to as "intelligent pigs."[*] They will typically use one or a combination of:

- magnetic flux leakage (MFL);
- ultrasonic technology (UT) ;
- electromagnetic acoustic transponder (EMAT);
- caliper interior measurement; and
- profile measurement and mapping (inertia measurement unit).

MFL tools detect metal loss defects in or on the pipe, such as corrosion or mechanical damage. MFL tools induce a magnetic field and when the tool passes a defect, the magnetic field is disturbed. That is, it "leaks" and the disturbance pattern is used to determine the extent and depth of the defect. ILI tools have magnetization oriented longitudinally (parallel to the axis of the pipe) or circumferentially. The likely orientation of the defect in the pipe wall determines which magnetization direction is appropriate. With complex metal loss, it is sometimes necessary to run both types of tools.

MFL tools fall into two basic groups:[†] standard (low) resolution, and high resolution. Although some applications may require low resolution (such as for screening purposes), high resolution is the BAT, and is the industry standard on both oil and gas pipelines.

[*] This differentiates them from cleaning pigs—the term "pig" most likely originating from the appearance of the cloth bundles and the likelihood that they were used to clean wax and debris from early oil lines.

[†] The groups differ on the level of magnetization, and number and type of sensors.

UT can detect cracks, crack-like defects, and metal loss (often associated with welds, but also with a damage type known as **SCC** in the body of the pipe). In UT tools, an acoustic transmitter sends out a signal. The signal's flight and echo return times are used to determine the location, type, extent, and depth of defects. UT can only run in a liquid pipeline because it requires acoustic coupling between the tool and the pipe, although it can run in a liquid slug in gas pipelines (often a slug of diesel oil carrying the UT ILI tool batched between two "dummy" pigs).

EMAT, an acoustic technology for both liquid and gas pipelines, also detects cracks in pipe. EMAT electromagnetically vibrates the pipe and measures the response, much like the difference between the difference in the tone of a bell with and without a crack. By analyzing the acoustic signal the pipe transmits from the vibration, the tool determines the location and dimensions of crack-like features. EMAT does not need an acoustic coupling like UT does, so is particularly useful in gas pipelines.

Though an emerging technology, EMAT is more generally described as a controlled implementation. The principal challenge is that it tends to find defects that are not there (false positives). However, the technology has been under development for some 20 years, and has become more sensitive and reliable so that now EMAT can be considered BAT for ILI crack detection in gas pipelines.[*]

The following list describes how **Caliper tools**[†] detect and size dents in a pipe.

- External forces on buried pipelines can distort the cross-sectional shape of the pipe.
- The two most usual types of damage are **ovalization** and dents, with dents typically being more serious.
- Dents on the bottom of the pipe can occur when the pipe is laid in the **trench** and rests on a rock. Dents on the top can indicate mechanical damage (from excavation on or near the pipe centerline).
- High-resolution caliper tools can also determine the shape of a distortion, allowing the operating company to evaluate the seriousness of the damage. This is particularly useful where a sharp change in the dent profile can indicate high, damaging local strains in the pipe that can lead to cracks (and subsequent failures).

High-resolution caliper tools can be considered BAT for detecting, sizing and profiling dents in oil and gas pipelines.

Profile measurement and mapping (inertia measurement unit or IMU)) can identify strains in a pipe. When combined with GIS, IMU is the BAT for strains from soil movement, changes in direction, and mapping of the pipe centerline. When run in the as-installed state, the **IMU tool** can map and validate the design of construction bends.

---

[*] EMAT replaces an earlier technology known as Elastic Wave, which relied on acoustic coupling through liquid-filled wheel sensors between the tool and the pipe.

[†] A caliper tool has a circumferential array of sensor "fingers" that ride on the inside surface of the pipe, which deflect when they encounter a distortion of the cross-section.

The Use of ILI Tools in Combination With Other Tools

Calipers and metal loss detection tools

A serious complication with dents (particularly top side dents likely from mechanical damage) is that it can have a gouge. When the stress concentration of a gouge combines with cross-sectional distortion, a leak or rupture is quite likely to occur.

Caliper tools alone cannot detect this damage, so they must combine with a metal loss detection tool (MFL or UT). Although not its principal purpose, MFL can very successfully detect both top and bottom side dents and their orientation. If an MFL detects dents (especially where metal loss is also detected), the BAT is to evaluate the dent and gouge damage based on the information from both tools.

ILI with IMU to evaluate soil movement strains

Soil movement (from slope instability, settlement, **frost heave** or seismic activity for example) can impose strain on buried pipelines beyond those experienced under normal operating loads, (principally internal pressure or thermal loading). This strain can be evaluated from changes in the longitudinal profile of the pipe and the technology best suited to detect it is an ILI tool fitted with a **low-drift IMU**.[*] To calculate strains in the pipe, operating companies compare the original, as-installed pipe profile with the profile resulting from the soil movement.

Validating ILI measurements

Although ILI tools have become highly reliable and accurate, their results must still be validated against measurements from the field. The typical steps are listed as follows.

- ILI results are plotted against field measurements of defects (like depth of metal loss, for example) on a conventional x-y graph. These graphs are known as “unity plots.” Ideally, results would line up on a 45-degree straight line, splitting the two axes. (ILI on the x-axis, and field depths on the y-axis, for example). In reality, some scatter around the 45-degree line comes principally from the tool’s measurement tolerance.
- Typically, the tool must measure depths to within plus or minus 10% of the pipe wall thickness on 80% of the measurements. If results fall outside the tool tolerances, the internal algorithms in the tool that convert signals to measurements must be adjusted, or the tool re-run.[†]

6.1.1.2 In-Service Hydro Testing

Companies operating pipelines must periodically assess the integrity of the pipeline to detect degradation like corrosion, crack formation or accidental mechanical damage that might have

---

[*] The IMU consists of a series of accelerometers and gyroscopes. The unit determines profile changes by measuring changes in accelerations, pitch, roll and yaw of the tool detected by the gyroscopes. This technology originally guided missiles and other **unmanned aerial vehicles**. It essentially works in reverse for pipelines. Rather than the IMU directing the vehicle, the pipe directs the vehicle (ILI tool) and the IMU records the changes in direction. This provides information to determine the longitudinal profile of the pipe.

[†] Since the tool is generally propelled by the oil or gas flowing in the pipe, and since this and the loads on the ILI tool vary with vertical profile of the pipeline, a speed excursion can be a source of measurement errors. Advanced ILI tools have “by-pass” capabilities that allow the flowing oil or gas to pass by the tool in a controlled manner and thereby provide better control of the speed of the tool.

occurred from excavations carried out close to the line or even accidentally on the ROW (during maintenance activities for example).

Three common methods are:

- ILI;
- pressure testing (mainly hydro testing); and
- direct assessment.

Typically, ILI best detects and sizes defects. In cases where ILI is not feasible (due to constrictions in the line for example), an **in-service hydro test** best assesses integrity. Hydro testing can also be considered a BAT in some cases where cracking is suspected (as explained below).

In an in-service hydro test, water is pumped into a pipe segment to see if water releases into the ROW, which indicates a failure in the pipe body. The breach then must be repaired and the test is repeated or continued until successful at the required test pressure.

In-Service Hydro Testing:

- is similar to the commissioning hydro test that proves the line's initial soundness;
- requires that product first be removed from the test segment and water then sourced and pumped in to fill it completely; and
- must have the water disposed of when complete, same as with a commissioning hydro test.

The difference with an in-service test is that the water might be contaminated by residual product in the pipeline segment, so disposal is more complex. It is also possible to pressure test using the product in the line. This is seldom conducted, however, because a rupture or leak of oil could cause ecological damage, and gas (being a compressible fluid) could cause an explosive rupture, creating a safety hazard.

Pressure Level and Spike Testing

In a spike test, the basic test pressure levels are the same in in-service and commissioning tests. The pressure goes above the normal strength for a short time (typically 125% of the maximum operating pressure, for 5 to 15 minutes).

Spike tests are best practice, particularly with possible cracking damage (such as Stress Corrosion Cracking).The stress during a spike test can be between 100% to 110% of the steel's specified minimum yield stress, or SMYS (the stress level at which permanent deformation of the steel under a load starts to occur.)

ILI and In-Service Hydro Testing BAT
ILI is now universally accepted as the BAT to assess blunt defects like corrosion damage. While ILI crack-detection has developed significantly in the last 5 to 10 years, a hydro test with a spike test component is the BAT for assessing crack-susceptible pipe segments.

However, the best use of available technology is to identify the most critical segments in the pipeline if reliable ILI results are available, then subject only those segments to a hydro test. Whatever the pressure test methodology, the test only provides a snapshot at the time of the test, and offers no predictive information. Pressure testing also only addresses the threat of overpressure. It gives essentially no information on the pipe resistance to other threats, such as ground movement, incorrect operation or mechanical damage.

6.1.1.3 Direct Assessment

Direct Assessment (DA) technology is capable of indicating potential degradation mechanisms (like coating damage or areas of low **cathodic protection**), and supplements hydro testing or ILI results. It is often an alternate to hydro testing in lines where ILI is difficult to use.

The technology boils down to:

- ***pre-assessment:*** to identify areas of concern;
- ***indirect inspection:*** to detect potential damaging conditions, such as external coating damage;
- ***direct examination:*** physically examining by measuring defects in areas of potential damage; and
- ***post-assessment:*** assessing the integrity of the pipe after analyzing results.

Using DA
Full protocols are only available for external corrosion and stress corrosion cracking hazards. Therefore, pipeline operating companies that consider DA on segments they assess to be un-piggable by ILI must account for DA’s limitations to assess the pipeline for other hazards (such as **geotechnical** loads, mechanical damage, or incorrect operation).

Operating companies only totally rely on DA to assess integrity when in-service failure risks are low. That said, the best use of available technology is either DA combined with ILI, or with in-service hydro testing when a pipeline segment is demonstrably non-piggable.

6.1.1.4 Leak Detection

Any unplanned release of product from a pipeline is unacceptable. If there is a leak, the integrity of the pipe has been compromised and remedial action must address and prevent it from developing into a pipeline rupture. Therefore, detecting leaks early is essential.

In principle, leaks can be detected at the pipeline control center through mass balancing measurements. Mass balancing compares the amount of product entering a pipeline segment with the amount exiting. If less comes out than went in, there is most likely a leak in the segment.

Limitations to Mass Balancing

1. Mass balancing techniques can fail to detect very small leaks, due to possible measurement inaccuracies or variations in operating conditions.
2. **Slack flow** in liquid pipelines can send ambiguous signals to the control center. **Slack flow** is when voids in the product stream develop from large pressure differences over a section of pipeline. These voids often result from rapid and large elevation changes. Where possible, the detailed pipeline design should minimize **slack line flow**.

Other leak detection methods available and in development are included in the following list.

- ***Acoustical***, in which equipment passing through the pipe in the product stream detects acoustic signals associated with leaks. This can also be considered an emerging technology as it is in controlled implementation.
- ***Computational monitoring systems*** **(CMS)**, which use input from hydraulic modeling and operating condition measurements (e.g., flow and temperatures).
- ***Land owners and land users' reports*** (including odours and sheen on water bodies).
- ***Aerial surveillance,*** which uses laser technology and flame ionization technology to detect vapour associated with a leak. It also directly observes product on the ground, dead vegetation and so on.
- ***Aerial and ground-based line patrols.*** Depending on risk considerations, the frequency of these can vary from bi-weekly to bi-annually.

BAT for leak detection currently combines, principally, mass-balancing, CMS, and surveillance.[*] Flows, pressures, and temperature measurements used in mass-balancing and CMS are monitored and relayed to the control center via SCADA. SCADA operates with coded signals over communication channels – typically using one communication channel per remote signal source (programmable logic controllers at compressor and pump stations; remote terminal units at key locations). In addition to logging data, this system is capable of analyzing and displaying the data and interacting with data from compressors and pumping units and valves through human-machine interface software.

Emerging Technology

Locating the Exact Leak Source

For a successful emergency response, crews must identify the exact leak source. Three promising emerging technologies are described in the following list.

- ***Aerial-based optical and infrared thermographic*** methods that can detect underground leaks, and that appear to be more precise than either flame ionization or laser-based technologies.
- ***Fiber optics*** applications that either detect temperature differences or acoustic vibrations associated with leaks. These might not be practical or feasible to install on existing pipelines, so should be carefully evaluated at the design stage.
- ***Complementary computational pipeline monitoring (CPM)*** capability, which uses parallel systems with different technology to add computational redundancy—that is, to gather data by several methods. In this method, one server has different hardware and technology than another, and each has independent field data gathering systems to

[*] See section 6.2.5 (Line Patrol).

recognize leaks. The two systems measure results of different physical variables (e.g., flow, pressure, temperature, density). For example, if one CPM system relies on flow measurements (such as the line balance method), the second CPM could measure pressure.

Detecting Leaks

UAVs (more commonly known as drones) may make aerial ROW surveillance and leak detection more frequent and cost effective. These advanced, remotely piloted aircraft:

- typically already have cameras to record photo, video and audio, and can stream to the controller on the ground; and
- could be developed to carry other leak detection apparatus such as infrared heat signature detectors and other **hydrocarbon** and GHG detecting technologies.

Unmanned Aerial Vehicle (UAV)

Barriers to using these drones in pipeline surveillance include:

- undeveloped regulatory approvals in North America;
- weather conditions; and
- keeping the drone within the visual line of sight of an operating company for non-military purposes.

CPM includes hardware and software advancement to better detect and locate leaks. Its advantages include:

- software that identifies intelligent flow balance, negative pressure wave, dynamic pressure, flow rate modelling and acoustic-noise correlation;
- communication abilities that include internet computer and communication protocols, line-of-sight radio, GSM and satellite uplink;
- electrical or solar powering; and
- a control panel that allows on-board data storage to ensure that data are saved during long communication outages.

Canadian research and controlled implementation of technology able to detect and analyze very small concentrations of leaked hydrocarbons associated with facilities has the potential for more general application to pipeline leak detection. An aspect of this work that could facilitate this application is the miniaturization of the measuring and real time analyzing equipment so that it can be routinely deployed continuously or pipeline maintenance vehicles, thereby providing essentially continuous, wide-ranging surveys. Further miniaturization is planned to allow the equipment to be deployed using unmanned aerial vehicles (drones) to carry out more focused surveys. In short, technology advancements drive leak detection improvements with better real-time data collection, analysis, location identification and communication.

6.1.2 Pipeline Integrity Activities*

6.1.2.1 Risk Assessment

Section 2.1.3 (Modeling for Design Conditions) discusses risk assessment at the design stage. It is also valuable for assessing operating pipeline integrity and deciding on maintenance options.

The BAT to assess risk is **QRA**, though semi-quantitative methods are often used, based on risk indices that consider design and operating conditions and consequences of failure.

6.1.2.2 Defect Evaluation

When ILI detects anomalies (or when they are observed directly during an excavation), they are evaluated to determine if they are to be considered defects according to regulatory criteria, in which case they must be repaired. Assessment methods have improved substantially over the past 20 years. Current assessment methods provide a highly accurate and conservative estimate of failure stress due to the existence of a defect in a pipe—particularly in the case of blunt metal loss features such as corrosion.

The BAT to assess such defects is one based on detailed direct measurement of the metal loss dimensions and depth profile on the excavated pipe at the point of indicated damage, and use of these measurements in conjunction with standard algorithms to determine the failure pressure at the damaged area.

Measuring Metal Loss Damage
Simple mechanical methods such as pit gauges continue to be used in some instances to measure metal loss damage. However, the BAT are based on laser measurements using hand-held equipment suitable for use in the excavation ditch (once the pipe coating has been removed, the pipe cleaned, and sand-blasted if needed).

Laser-based technology:

- can be rapidly applied;
- is at least as accurate as mechanical measurements;
- gives consistently repeatable measurement results; and
- provides useful graphical visualization of the damage in addition to basic defect data profile information.

Assessing Cracks
Assessing cracks and crack-like defects considers two failure modes:

- brittle fracture starting at the tip of the crack and proceeding rapidly through the uncracked ligament of steel; and
- ductile failure of the ligament itself, due to over-stress in the ligament from loss of pipe wall thickness caused by a crack.

* It is beyond the scope of this document to give detailed accounts of all possible defect assessment methodologies. A useful reference that provides procedures and assessment methods is the Pipeline Defect Assessment Manual (PDAM) compiled and developed by PENSPEN Ltd, UK.

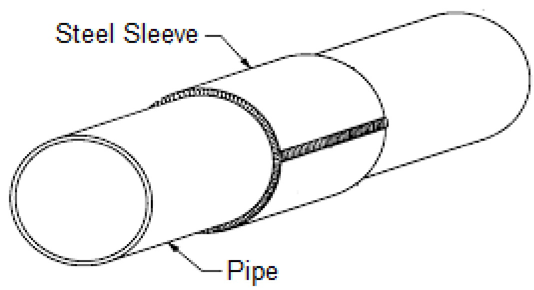
Which of these two mechanisms causes ultimate failure depends on the stress level at the crack and the toughness of the steel (toughness simply being the property of a particular steel that resists cracking).

Whereas simple failure assessment diagram (FAD) approaches are available (see, for example, API 579 and BS 7910), the BAT (in terms of accuracy and general applicability to complex cracking) is to use commercially available crack assessment software.

6.1.2.3 Defect Repair

When measuring and assessing reveal that an anomaly is, in fact, a defect, it is repaired. This is done most simply by cutting out the defective pipe section as a cylinder and replacing it with sound pipe. However, this method disrupts service and product must be removed from the pipeline, so operating companies have developed other effective repair methods, such as using:

- steel sleeves welded over the defective area;
- composite plastic material wrapped around the area; and
- application-specific repair shells that reinforce the area and prevent further development of the defect. These repair shells are especially useful for repairing cracks and crack-like defects.



Example of a steel sleeve welded over a defective area on a pipe

Best Available Repair Strategies

The key principle is to select the repair method appropriate for the pipeline configuration, and for the type and extent of the damage. While this document cannot cover all available repair technologies, general guidelines are described in the following list.

- ***Extensive corrosion over most of the pipe joint:*** remove as a cylinder and replace with sound pipe.
- ***Local areas of internal or external corrosion:*** a steel repair sleeve is sufficient and economical.
    - ***Internal corrosion***: This repair sleeve must be welded at the ends to make it contain pressure, since the sleeve does not inhibit the internal corrosion, which could expand through the wall of the pipe.
    - ***External corrosion***: this can be repaired without welding by using a plastic composite wrap. As with fiber glass moldings, a version of this wrap can be "laid up" to reinforce bends in a pipeline. Such repaired regions are generally stronger than the adjacent sound pipe.
- ***Damage involving cracks, crack-like features, or gouges****:* requires defect-specific repair shells. For example, one shell is applied hot so that as it cools it puts a compressive load on the pipe. This not only reinforces cracking damage, but actually closes the crack and prevents further propagation.

6.1.3 Failure Investigation

If pipelines are designed, constructed, operated and maintained to NEB regulations and Canadian national standards, the likelihood of a failure of any particular segment of the pipeline is very low. However, no method of transportation is infallible. In the unlikely event of a pipeline leak or rupture, priorities are described in the following list.

1. To secure the site and prevent further harm to people or the environment, or damage to property. This might involve isolating the failure site, evacuating personnel or dealing with the outflow of product (fire or spilled product) and is generally as described in section 6.3.1 (Emergency/Spill Response).
2. To perform a preliminary investigation of the failure and to secure evidence (including mapping and retrieving damaged parts).
3. To perform a detailed analysis on the failure. In this step, metallurgical examination of the failed parts is generally required, and the results of this examination, combined with site observations, are used to determine the root cause of the failure and complete the investigation.

The Transportation Safety Board (TSB) has the mandated right by legislation to choose to be the lead investigator. In this case, only the TSB is authorized to determine cause and contributing factors of the failure. Nonetheless, the NEB will always also investigate the failure as a regulatory oversight action and to communicate the findings to industry in the effort to mitigate or prevent any future loss-of-containment incidents.

6.2 Operation: Environmental Considerations

In the operational phase of pipeline construction, environmental considerations include:

- post-construction monitoring;
- noise and light pollution;
- **erosion** and **sediment** control;
- **subsidence** over the pipeline;
- line patrol;
- controlling vehicular traffic access;
- managing **invasive species;**
- conserving rare species; and
- managing air emissions.

6.2.1 Post-construction Monitoring of Environmental Features

Operating companies conduct post-construction monitoring for a specified time after the construction project has been completed to assess how effective **mitigation** has been at reclaiming land and establishing vegetation. It is also used to track deficiencies in the ROW following construction for planning additional reclamation and maintenance activities. The NEB may require periodic submission of reports to verify that reclamation of the project is proceeding as planned, and that any outstanding issues for landowners are being addressed.

Monitoring programs are project specific and may include soil, crops, native vegetation communities, **watercourses** and wildlife habitat features. Post-construction monitoring programs

(PCMPs) for projects in the caribou range typically assess vegetation recovery and the effectiveness of offset measures.[*] For example, minimizing brushing can accelerate natural recovery of vegetation along the ROW. An example of emerging technology includes handheld devices that can be used to accurately determine monitoring locations and to capture and upload monitoring data to remote databases.

Operating companies are increasingly using high-definition digital aerial photos and satellite images to monitor and measure:

- post-construction changes in streambeds at crossings;
- changes to stream **armouring;**
- **impoundments** of water across the ROW;
- wetlands size and function indicators;
- on- and off-ROW vegetation height and crop health;
- ATV and vehicle tracks on the ROW; and
- changes in the location of valves/risers/pipeline markers due to terrain movement.

During construction, the operating company can fix the precise location of each element or feature. Subsequent automated scans can indicate changes to these metrics and indicate where an on-the-ground inspection must be made. These metrics could be used for future decisions about reclamation success and for criteria for measuring reclamation and **mitigation** effectiveness.

6.2.2 Noise and Light Pollution

Noise and light pollution considerations in the operation phase are similar to those outlined in the construction phase (see section 4.2.2, Noise and Light Pollution). During pipeline operation, equipment generates noise (such as from gas turbines, compressors, pumps, motors, coolers and fans). Assessing the noise of pipeline-associated facilities can contribute to information on **mitigation** options. Provincial or municipal regulations establish noise limits to guide planning and **mitigation** requirements for operations. [85,86]

Reducing Noise

Methods to reduce noise include:

- selecting equipment with lower sound power levels; [87]
- installing silencers for combustion air inlet, gas exhausts and **blowdown** vents;
- installing noise emitting equipment inside buildings with acoustic wall and roof designs;
- designing equipment buildings with sufficient ventilation so that doors and windows remain closed;
- considering acoustic design for building ventilations, such as **louvers**, **ridge vents**, inlet fans and exhaust fans;
- orienting noise emission sources away from noise sensitive **receptors**;
- using an acoustic barrier for outdoor noise sources; and
- using structures or natural terrain to screen noise sources from **receptors**.

[*] See section 2.2.1.5 (Caribou Habitat Protection and Restoration).

Reducing Light

Operating facilities can be significant light sources. Measures to address potential light pollution are best developed at the design stage. **Mitigation** strategies include:

- installing full horizontal;
- cutting off light fixtures to maximize the control of light spill;
- planning the parking and fueling stations so that headlights are not directed toward human **receptors** or key wildlife areas;
- using motion-activated lights to minimize unnecessary light; and
- leaving standing vegetation in place to form a light block from the facility (whenever possible).

Emerging Technology

Various advances include:

- noise monitoring stations with web-based connectivity that provide real time information, such as noise level, audio recording and text messaging, if a certain sound level is exceeded;
- Helmholtz systems to suppress noise at compressor stations;[88] and
- energy-efficient light-emitting diode (LED) lights on the warm (red light) end of the light spectrum. These replace the more common blue light LED that are more bio-active (disruptive to animals and humans).

6.2.3 Erosion and Sediment Control

Erosion and **sediment** control issues during operation are similar to those during construction.[*] During the operational life of a pipeline or facility, several factors may come into play:

- wind and water **erosion;**
- natural realignment of water courses; and
- flooding or disturbance due to recreational vehicle use on the pipeline ROW.

Line patrol[†] is key to detecting these potential issues early. Re-established vegetative cover and/or slope stabilizing materials can manage most **erosion** and **sediment** concerns during normal operating conditions.

During **upset events**, such as slope failure or pipeline exposure, the BAT and the emerging technologies listed in pre-construction planning and construction[‡] may apply to **sediment** and **erosion** concerns.

6.2.4 Subsidence Over the Pipeline

Several factors may lead to subsidence or settlement over the pipeline:

- challenges during **backfilling** of the pipeline **trench**;
- **backfill** material that is mobilized by surface water;
- **groundwater** travelling along the pipeline; and

---

[*] Covered in section 4.0.(Pre-Construction Planning and Construction)

[†] See section 6.2.5 (Line Patrol).

[‡] Section 4.2.5 (Low Impact Pipelining).

- wider scale **geotechnical** instability or failure* such as **washout**, ground movement caused by cyclic freezing and thawing, unauthorized excavation activities near the pipeline, movement from earthquakes, or slope instability.

6.2.4.1 Subsidence Prevention

BAT to prevent **subsidence** due to **erosion** near **watercourse** crossings, during excavation **dewatering** and due to **groundwater** movement along the pipeline are described in the following list. [42,43,44,46,48]

- Avoiding **backfilling** with gravel or other porous fill for long trenches in wetlands and where static **groundwater** levels are above the **trench** bottom. Instead, install impermeable plugs to prevent flow along the **trench**.
- Installing **trench breakers** (**ditch plugs**) on approach slopes and stream banks where organic or erodible soils exist. This prevents excessive **groundwater** discharge to the **watercourse**.
- Installing sub-drains where **surficial** springs/**groundwater** seepage exists. This provides an outlet for seepage to the surface.
- Closely monitoring excavation **dewatering** rates and the presence of fine soils and high turbidity. This avoids soil **subsidence** or damage to nearby structures.
- Implementing **mitigation** measures if **groundwater** could flow along the pipeline ROW during **dewatering**. For example, installing **sheet piling** around the excavation or relief wells to intercept **groundwater** before it can enter the work area.

6.2.4.2 Working on Slopes†

BAT when working on slopes includes: [42,43,44,45,46,47,48,60]

- observing the visual condition of the slope for evidence of **slumping**, rotational and/or translational failures;
- **backfilling** from the bottom to the top and providing a stable toe design, when **backfilling** a slope; and
- making provisions for **groundwater** migration on pipelines installed transversely along slopes (this can be completed by installing subdrains and/or using porous **backfill** that will not inhibit **groundwater** moving across the transverse **trench)**.

Emerging Technology

Emerging technology includes:

- remote sensing, aerial or satellite-based digital terrain mapping to detect subsidence along the ROW—such as **LiDAR** that uses lasers to get detailed surface elevation data;
- **GIS** tools to identify and map zones that have higher potential for **subsidence** based on criteria such as material texture, time of construction and construction equipment used; and
- monitoring zones of known or possible subsidence using settlement meters or inclinometers equipped with telemetry data transfer capability.

---

* As noted in CSA Z662- 15—Oil and Gas Pipelines Section H.2.6.8.

† Other BAT for **subsidence** are those in section 4.2.5 on **backfilling**.

6.2.5 Line Patrol

Line patrols involve operating companies visually inspecting the pipeline and associated ROW to:

- identify anomalies for further investigation, such as **erosion**, **trench subsidence** or pooling, and evidence of leaks; and
- document encroachment onto the ROW by third parties.

Fixed-wing aircraft and helicopters are typically used to conduct **line patrols**. Operators do localized or follow-up surveys with ground-based vehicles, such as pick-up trucks, all-terrain vehicles (ATVs) and snowmobiles.

Most patrols have little environmental effects, although the impact of **line patrols** varies by location. Where a pipeline crosses an important wildlife habitat, and particularly during sensitive periods such as nesting and calving, **line patrols** may sometimes cause a sensory disturbance. As well, ground-based **line patrols** may cause localized rutting and vegetation damage, if operating companies conduct them during unsuitable weather or use inappropriate vehicles (i.e., 4x4 trucks rather than ATVs or on foot).

Best practices for conducting line patrols include:

- training patrol staff on how to identify and manage environmental concerns in their operating area;
- scheduling patrols during lower sensitivity periods; and
- maintaining setbacks, including altitude limitations, around known wildlife habitat features (year-round or during defined RAPs).

Some sites may require seasonal avoidance measures if pipelines are close to grouse **leks**, raptor stick nests or **ungulate** breeding and lambing or calving areas.

The general recommendation is to provide line patrol contractors with sites and their associated timing, setback, and altitude restrictions embedded in GPS files.

Emerging Technology

Line patrols by UAVs have great potential.[*] Remote sensing options and high resolution imagery are also becoming more common and accessible, which may reduce the need for manned aerial or on-the-ground visits.[89]

6.2.6 Maintaining Access Control of Vehicular Traffic on ROWs

Controlling human and vehicular access along pipeline ROWs may be necessary for several reasons, including reducing sensory disturbance and mortality risk to wildlife, and protecting **watercourse** crossings and **erosion** prone slopes.

Pipeline projects often include effective access control as an approval condition, and some have developed access management plans. However, these plans may be difficult to implement for legal and jurisdictional reasons, particularly on publicly owned land. Controlling access in

[*] As described in section 6.1.1.4 (Leak Detection).

certain areas may be a condition of regulatory approval. There may also be legislated restrictions on vehicle use on public land.

Current Methods

At present, operating companies use the methods in the following list to discourage access to or along pipeline ROWs.

- Placing physical barriers at access points, including road trail crossings. Examples include boulders, vegetated soil mounds, post-and-rail fences, chain-link fences and **rollback** of cleared vegetation. These barriers interfere with line of sight so people are less likely to seek access or travel along the ROW. **Rollback**, if properly applied, can discourage people from riding their all-terrain vehicles in these areas (even when they can navigate around many other barriers).
- Deactivating and removing off-ROW access roads used during construction (if they are not required for operations).
- Placing signage at access points to alert the public to the presence of the pipeline.
- Educating the public—especially hunters, ATV and snowmobile users—on the need for access control.
- With consideration of the pipeline, re-establishing shrubs and trees across the ROW.
- Using remote cameras and ROW patrols to provide evidence that will assist local or provincial policing agencies with enforcement (e.g., fines) in situations of trespass and damage to private property.

Emerging Technology

Remote camera technology is currently being piloted to monitor wildlife activity (e.g., caribou) and human use of pipeline ROWs in northern Alberta and BC.

6.2.7 Invasive Species

BAT and emerging technologies related to managing **invasive species** in the operations phase of the pipeline lifecycle are the same as described in the pre-construction planning and construction section.[*]

6.2.8 Rare Species Conservation During Maintenance Activities

Many potential issues and **mitigation** for rare species that apply to maintaining pipeline and facility sites were addressed in the Design and Pre-Construction Planning and Construction sections.[†]

A critical factor in protecting rare species sites in this phase is managing and transferring information from the planning, construction and commissioning stages as they hand off to operations. This is best accomplished by GIS-based systems that can store and transfer spatial data sets tied to specific locations along the ROW, such as the location of rare plant communities, wildlife habitat features or **mitigation** measures implemented during construction.

---

[*] See section 4.2.8 (Invasive Species Management).

[†] Such as section 4.2.3 (Construction Timing), section 2.2.1.4 (Species at Risk), and section 2.2.1.5 (Caribou Habitat Protection and Restoration).

If baseline data for rare species does not exist for an operating pipeline, the company will conduct a screening and develop **mitigation** for rare species (and other environmental resources) before maintenance activities commence. This may include:

- ***reviewing online registries*** of rare species to determine if they may be present in the maintenance location;
- *consulting with local authorities* on rare species and their habitats near the proposed maintenance activities;
- ***reviewing pipeline company's files*** for known rare species' locations and their habitats along the pipeline ROW;
- ***conducting pre-construction screenings*** to determine if a species' habitat is near the proposed maintenance activities. If warranted, conducting field surveys using qualified biologists and follow provincial species survey protocols may be appropriate;
- ***consulting with local authorities*** on timing activities and **mitigation** measures to minimize disturbance to rare species and their habitats during sensitive time periods;
- ***recommending mitigation measures*** for construction if rare species are present, such as avoidance, **timing windows**, temporary setbacks, or physical measures. Exclusion fencing is one physical measure to minimize species of concern entering work areas during maintenance activities; and
- ***managing vegetation*** along the ROW to regenerate and enhance habitat for rare species.

Emerging technology to minimize impacts to rare species includes:

- ***handheld data collection software and tools***, to record the location of rare species and habitat;
- ***devices such as smartphones and tablet computers***, to access online mapping tools. This allows field staff to determine if the proposed activities will impact rare species and their habitats prior to operations and maintenance activities; and
- ***online mapping tools***, for construction staff and environmental inspectors to identify rare species and habitat in the field and flag them for protection during construction activities in addition to those surveyed during the design of the activity.

6.2.9 Air Emissions Management

6.2.9.1 Managing Air Emissions During the Design Phase

Air emissions management BAT are generally incorporated in the design phase of the project.* At its simplest, BAT plans to release the smallest quantities of air contaminants or GHGs possible, while still maintaining the targeted production. At the design phase, this means:

- using low **nitric oxide** and **nitrogen dioxide** (NO_X) burner technology at a compressor station; and
- installing a floating roof on a **hydrocarbon** storage tank.

Leaks from valves, pumps and connectors can release VOCs and methane into the atmosphere during operation. Additional strategies for operating companies include:

- monitoring programs to assist in managing air emissions;

* See section 2.2.4 (Equipment Choices).

- conducting routine maintenance on a schedule; [90] and
- structured leak detection and repair (LDAR) programs along ROWs and at facilities to identify leaks and prioritize repairs[25, 90] (LDAR programs include aerial surveys along pipeline ROWs and passive or active plume imaging at facilities and along pipelines).

6.2.9.2 Blowdowns

Blowdowns of pipelines are necessary for various reasons, such as repairs or replacement of a section of pipe. Often, blowdowns vent gas directly into the atmosphere. However, it is also possible to:

- flare the gas;
- retain and re-compress the gas;
- reduce the pressure of the gas (a planned activity);
- reduce the volume of gas (a planned activity); and
- avoid a **blowdown.**

Venting is currently most common due to associated reduced outage length. However, an operating company can plan to flare the gas or to use a portable compressor unit to redirect gas from the section of pipe requiring de-pressurization to the adjacent, normally pressurized pipe section. Pull-down compressors are most appropriate for large pipelines operating at high pressures.[26]

6.2.9.3 Reducing Air Emissions During the Operations Phase

The operations phase relies on many of the same energy efficiency and fuel use measures that reduce GHSs during the construction phase. [*] It is cost effective and technically feasible to reduce GHGs by using vehicles, equipment and fuel that are energy efficient.[25] Compressor stations and **hydrocarbon** storage tank farms may use **optical gas imaging** (or equivalent) to detect leaks and prioritize repairs.[90] This technology can detect VOC and carbon dioxide (CO_2) leaks and assists operating companies to identify and prioritize leaks for repair.

Emerging Technology
Emerging technologies in optical gas imaging include aerial access to remote locations fixing infrared cameras or other imaging equipment to helicopters, aircraft or UAVs. These technologies may be particularly useful for surveys of long linear pipeline ROWs.

Carbon capture and sequestration is an emerging method used to dispose of facility CO_2. This process captures post-combustion CO_2 or stripped CO_2 from the raw gas stream, and injects it into a deep geological formation, which serves as a storage site. This technology is not yet widely used in Canada, however, some demonstration and commercial projects are underway.

New federal regulations will impose performance standards on equipment such as stationary spark ignition gaseous fuel-fired engines and non-utility boilers and heaters. The Base Level Industrial Emission Requirements (BLIERs) have been developed under the Multi-Sector Air

[*] Discussed in section 4.2.10 (Greenhouse Gas and Methane Emissions Reduction).

Pollutant Regulations (MSAPR) and limit the amount of NO_X that can be emitted from this equipment. Operating companies can manage NO_X emissions from existing compressor stations by installing engine/compressor control and monitoring systems. The systems can control the fuel-air mixture in the turbine to optimize combustion and reduce emissions.[91]

Recently, the CSA published standard Z620.1-16 "Reduction of fugitive and vented emissions for upstream petroleum and natural gas industry systems. This standard applies to unintentional and intentional (leaks and vents) hydrocarbon releases into the atmosphere and is to be used as a resource to inform management of fugitive and vented emissions from wells, pipelines and facilities associated with specific sectors (e.g., natural gas production, natural gas processing, crude oil production and shale oil). The standard outlines basic control strategy considerations and LDAR program design as well as quantification and mitigation options for a variety of common equipment types in the upstream sector.

6.2.10 Contaminated Sites: Assessment, Remediation and Monitoring

Various mechanisms may cause **hydrocarbon** contamination of soil and/or **groundwater** from pipelines and associated facilities, including:

- loss of pipeline integrity, leading to product releases (e.g., valve or tank failures, internal or external corrosion, pipeline breaks due to landslides, high stream flow events);
- spills from fueling and fuel storage facilities and vehicle roll-overs; and
- pipelines or facilities releasing petroleum **hydrocarbons** into soils, which may impact local **groundwater** if it occurs near the water table.

The risk of product release is confined to the operations phase when the pipeline and associated facility are in active use. However, soil and **groundwater** contamination could occur at every lifecycle stage. Consequently, much of the information provided below applies also to section 4 (Pre-Construction Planning and Construction) and section 7 (Deactivation, Decommissioning, **Abandonment**).

6.2.10.1 Assessing the Presence or Absence of Contaminants

Provincial and federal environmental authorities have developed a number of frameworks, guidance documents, standards and regulations for completing Environmental Site Assessments (ESA) to assess the presence or absence of contaminants in soil and/or **groundwater**.*

Operating companies often advance and characterize soil conditions and impacts with drilling techniques or test pit excavations. For example, Ontario's Guide for completing Phase II ESAs under Ontario Regulation 153/04[92] identifies appropriate investigation techniques, sampling devices, laboratory requirements for sample analysis and documentation standards for the field program.

Groundwater assessment techniques are also prescribed in many jurisdictions, including how to appropriately construct **groundwater** monitoring wells and sampling techniques. Ontario's

* Examples include CSA Z769.1 (R2013) by the CSA and the British Columbia Contaminated Site Regulation (under the Provincial Environmental Management Act).

Guide[92] requires standard operating procedures for monitoring well installation and **groundwater** sampling. Operating companies must use methods appropriate for the site conditions including access method, soil type, depth to **groundwater** and depth of suspected contamination.

6.2.10.2 Soil Contamination

When operating companies find soil contaminants as a result of petroleum **hydrocarbon** release from a pipeline or facility, they usually delineate the impacts through ESA (as noted above) and then excavate, remove and dispose of the contaminant. These strategies are typically the best short-term option, as they cost less and take less time (depending on access, depth and extent of impacts). If **groundwater** is also affected, after excavating the soil, the operating company will generally develop a **groundwater** treatment program that assumes the depth of **groundwater**, the type and concentration of contaminants and the extent of the impacts.

6.2.10.3 Petroleum Hydrocarbon Contaminant Treatment in Groundwater

Current technologies include:

- traditional pump and treatment with oil/water separators (for light non-aqueous phase liquids (LNAPL);
- granulated activated carbon (GAC);
- clay filters;
- **air sparging** to remove **volatile fractions** in **groundwater**; and
- monitored natural **attenuation**.

Risk Assessment
If **infrastructure** or on-going facility operations interfere with accessing or removing **groundwater** or soils, a risk assessment can determine if residual petroleum **hydrocarbons** remaining in the soils/**groundwater** pose a risk to human health or the environment. Most provinces and the federal government have frameworks for approaching and completing a risk assessment, to allow closure of a contaminated site.

Emerging ESA Technology
These ongoing technologies include:

- sampling alternative media, such as tree cores to characterize concentrations of contaminants in soil and **groundwater**;[93] and
- innovative sampling techniques, such as **solid phase micro extraction** (SPME) for assessing concentrations of contaminants in **groundwater** wells over longer durations.

Emerging Technology for Impacted Soils and Groundwater
"Green Remediation" is currently at the forefront of new approaches for these substances. These approaches focus on ways to reduce the **carbon footprint**, the net environmental benefit analysis (NEBA) and the ways to clean up the environment without causing additional GHGs or by-products. Some jurisdictions in the US have developed guidelines for practitioners on selecting "green" approaches to remediation. On example is adding biological matter/organisms (such as **biosolids** from wastewater treatment plants) to soils contaminated with petroleum **hydrocarbon** to increase biological activity and degradation of contaminants. In Canada, some municipalities

are exploring soil recycling or brokering of soils as sustainable approaches for soil **remediation**.[94]

"Green" **groundwater remediation** approaches for petroleum **hydrocarbon** impacts include:
- using oxygen releasing compounds for microbial stimulation in monitoring wells;
- finding innovating ways to run **groundwater** pump-and-treat systems to reduce or re-use waste by-products of treatment; and
- finding ways to reduce water volumes necessary for treatment.

6.3 Operation: Emergency Management

The NEB mandates that operating companies develop an emergency management program for federally-regulated pipelines that "*anticipates, prevents, manages and mitigates conditions during an emergency.*"[76] Detailed spill response, containment and reporting procedures are typically outlined in a company's corporate and/or project-specific emergency response plan, referred to as an emergency procedures manual under NEB regulations.

Best practices in an emergency typically include integrating personnel, facilities, equipment, procedures and communications into a common organizational structure under an incident management system that promotes an effective and efficient response. For example, the Incident Command System (ICS) is an on-scene emergency management system used to coordinate emergency response to an incident or incidents across jurisdictions and varying stakeholder interests.

The typical steps in response to a **hydrocarbon** spill involve:
1. initial containment and protection of resources;*
2. product recovery; and
3. **reclamation and remediation** of the affected area, plants and animals.

6.3.1 Emergency/Spill Response

This section provides examples of BAT and emerging technologies for spill clean-up techniques, products, reclamation and remediation, **dispersants**, and disposal of materials.

6.3.1.1 Clean Up Techniques, Products and Equipment

Containment and Recovery in Open Water
Hard booms are floated in the water with adequate height to account for wave action and a **sinking skirt** to intercept submerged product. **Booms** can be set to fixed points or mobile devices (e.g., boats) to deflect product to a recovery point, to concentrate the product or to reduce mobility until recovery can be completed. After the hard boom, recovery can be completed with:
- skimmers, such as rolling drum, gravity separation and selective membrane;
- sorbent material, such as pads, booms, or disposable or washable beads; or

* Processes and equipment used for initial containment and recovery are discussed in section 6.3.1.1 (Clean Up Products and Equipment).

- vacuum units.

If product thickness is minimal**,** adsorbent material (soft) booms can be set to **sorb** product on contact.

Streams and Rivers
In streams and rivers, hard or soft boom processes (as above) can be used with under flow **weirs** to catch additional flowing product. BAT also includes teams trained in containing and recovering spilled products. The emergency response plan typically outlines the type of training and its frequency.

Under frozen conditions in continuous ice, slot-cutting of trenches perpendicular to the estimated trajectory downstream of the release can intercept and recover product using vacuum trucks and extended hoses. This makes it possible to reach the locations from land or from safe locations on the frozen water body.

In discontinuous ice, fragmented ice, ice packs, or if the recovery team breaks the ice, it is possible to burn the product on site in areas where it accumulates. Responders must determine that risks of associated with burning and any potential environmental or socio-economic effects are acceptable or mitigated.

Containment and Recovery of Product on Land, Snow or Ice
These are recognized as BAT on land, snow or ice:

- using temporary **coffer dams** (e.g., water-filled dams) to block the product path or divert it to a collection point;
- trenching to block the product path or divert to a collection point;
- directly applying absorbent material; and
- applying solidifying–gelling material.

Dispersants
Dispersants are commonly used spill-treating agents (STA) and can be the most effective approach when factors such as the risks and rewards of applying them, weather conditions, and environmental and socio-economic sensitivities are considered. Sometimes conditions (e.g., large impacted areas or an area too remote for other possible strategies) make it difficult or impossible to implement traditional spill response strategies for releases on water. In such cases, **dispersants** can be considered if using them will:

- distribute the product at lesser concentrations in the water column or more evenly over the impacted area;
- reduce overall risk/toxicity to any **receptor** or to the overall ecosystem (e.g., higher protection of more sensitive **receptors**); or
- reduce the amount of oil migrating to shorelines, where it could strand or have adverse impacts on more sensitive environments or **receptors** (e.g., wetlands, estuaries with habitat, waterfowl).

BAT includes research and development around classes of chemical **dispersants**, which traditionally have been formulated and applied in marine environments.[95] The appropriate approval must be obtained from regulators prior to application of dispersants.

Emerging Technology for Clean-up Products and Equipment
The Canadian Pipeline Technology Collaborative (CPTC) is currently working on a study of BAT through their working group titled "CPTC National Spill Response Science, Technology and Innovation Program." The Royal Society of Canada's 2015 study on "The Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments"[96] recommended research to develop innovations in clean-up products and equipment. Current research is investigating applications and innovations in traditional chemical **dispersants**, **bioremediation** and physical methods such as **booms** and skimmers (e.g., high speed skimming technologies).

Other Emerging Technology
Other new or emerging technologies include:

- integrating real-time data from tablets, smartphones, and computer software applications into a common operating picture (COP) during a response. This also makes delivering information to stakeholders during a response more efficient;
- development of more sophisticated and user-friendly spill trajectory and fate models; and
- ongoing improvements in Spill Impact Mitigation Assessment (SIMA), also called NEBA, to select the best response techniques and equipment and minimize the impact of the spill on humans and the environment.

6.3.1.2 Reclamation and Remediation

Reclamation and remediation mitigate potential risks to people and the environment. Following containment and removal, reclamation and **remediation** efforts for impacted soil, water, **sediment**, vegetation, and shoreline entails:

- choosing a method and locations that prioritize affected environments of the greatest sensitivity and that have the ability to successfully remediate the resource;
- maintaining the first principles of reduction/removal of unacceptable environmental risk and net environmental benefit (vs. undue harm to the environmental resource in an attempt to achieve the complete removal of spilled product);
- employing a system to treat and remove the product on site. Example approaches include:
    - low/high pressure washing;
    - flooding and washing;
    - tiling of soils;
    - **bioremediation**;
    - selective harvesting of impacted vegetation (preserving root systems); and
    - monitored natural **attenuation** (i.e., degradation) rather than bulk removal of soils and/or vegetation;
- determining whether saturated or heavily impacted **sediment** or soils must be removed by excavation, based on the risks of toxicity or mobilization; and
- removing snow or ice from the site, and treating it or disposing of it.

The addition of petroleum-degrading micro-organisms to spilled product on site can accelerate the natural ability of an ecosystem to recover from a spill. Operating companies and regulatory agencies must monitor the indirect effects of the **inoculation** and of the nutrient addition usually associated with it, to evaluate the net overall effect on the site. They must also conduct a risk/reward analysis, especially for potential migration and impacts to domestic and potable **groundwater** supplies.*

6.3.1.3 Materials Disposal After Use in a Spill Response

Waste Disposal
BAT is for operating companies to treat or dispose of the material generated by the response effort at the closest disposal or treatment facility capable of accepting the waste. For the recovered spilled material, BAT is to recycle, re-refine or downgrade the material for use as a lower use **feedstock** or fuel. If no facilities exist within a reasonable distance, or if the location is remote, BAT is for the operating company to construct a treatment facility for the waste. If this is not possible, a disposal facility for the waste may be required.

Emerging approaches to manage waste generated during spill response have focused on finding innovative solutions to divert or reduce waste streams from disposal by landfilling, where feasible.

* Emerging technologies in this area are the same as those described in section 6.3.1.1.

7.0 DEACTIVATION, DECOMMISSIONING AND ABANDONMENT

A company may apply to the NEB to deactivate, decommission or abandon a federally-regulated pipeline or facility. To abandon pipelines specifically, a company may choose to remove the pipeline completely, remove it partially or abandon the pipeline in place.

The decision to remove or abandon a pipeline in place often depends on the current and future use of the land and potential environmental impacts.[97] The NEB provides guidance to industry about developing **Abandonment** Plans for federally-regulated pipelines, including requirements to seek input from landowners, technical experts and other stakeholders.[97]

Decommissioning involves the same activities as abandoning in place. However, the regulatory requirements are different in that decommissioning does not require a public hearing before it is approved. Decommissioning can only be used where it can be demonstrated that the service originally supplied by the decommissioned line can be continued by some other means.

7.1 Deactivation

When an operating company wishes to temporarily deactivate a pipeline segment, typically it must:

- isolate the pipeline segment to be deactivated (including closing valves to block off incoming and outgoing flow from the segment);
- remove existing product from the isolated segment;
- block off the segment at each isolation point (by installing blind flanges for example);
- confirm that the piping segments can be drained and vented;
- remove instrumentation and plug sensor connections;
- remove residual products from the isolated segments by pigging, steam or water jetting, chemical agents or other suitable means, and purge and fill the segment and components with low pressure nitrogen;
- monitor the pipe segments by checking the nitrogen pressure; and
- maintain **cathodic protection** current and voltage levels, and continue to monitor these to meet CSA Z662-15 requirements.

7.2 Abandonment

When a line is to be abandoned, a company must demonstrate that it will abandon the pipeline in a way that protects the environment and the public. Further, the company must plan for, prevent, manage and mitigate potentially dangerous conditions associated with the abandoned line.

7.2.1 Method

7.2.1.1 Choosing an Appropriate Method for Abandonment

When choosing an appropriate method for **abandonment**, the land use category where the pipeline is located is the most important consideration.[98] CEPA presents a matrix correlating land use categories and appropriate abandonment methods. The choices are:

- abandoning in place;

- abandoning in place with special treatment; and
- removing according to various land use categories. [99]

Environmental assessment as part of abandonment

CEPA recommends that operating companies weigh the risks and potential effects related to abandoning a pipeline in place against those associated with pipeline removal.[99,100] Quite likely, companies will use a combination of strategies, which conditions determine, when abandoning large sections of pipeline.[98,99]

7.2.1.2 Additional Key Considerations

Additional key considerations to determine the method of pipeline abandonment include:

- existing and potential land use;
- road and railway crossings;
- **watercourse** crossings;
- environmentally sensitive areas;
- effects on terrain and water;
- soil and **groundwater** contamination;
- pipeline properties (e.g., diameter, coatings); [98,101] and
- discussions among the pipeline company, local stakeholders, landowners and regulatory agencies.

In all cases, CSA Z662-15 (section 10.16.3)[101] requires removal of all above-ground facilities associated with the abandoned pipeline, such as:

- **block valves;**
- **cathodic protection**, for example thermoelectric generators, rectifiers and **test leads**;
- SCADA; and
- buildings.

7.2.1.3 Additional Environmental Considerations

Timing the removal of these facilities to avoid environmentally and socially sensitive periods such as bird nesting and agricultural harvesting is a key strategy for reducing environmental effects.

Pre-existing contamination may be associated with above-ground facilities, such as **hydrocarbon**s, **PAHs**, **polychlorinated biphenyl** or naturally occurring radioactive materials (heavy metals). Performing an ESA before abandonment facilitates appropriate planning for contamination containment and removal during abandonment activities. Operating companies should reference the NEB Remediation Process Guide[102] when dealing with contamination issues on federally-regulated facilities.

Operating companies should develop environmental protection **measures** when pipelines or facilities are removed, such as soil handling procedures, contingency plans, weed management, protection of sensitive cultural and environmental features, and reclamation and monitoring plans.[98]

Adding a proportionate volume of soil may be necessary where pipeline is removed, to prevent a sunken ditchline. This includes **compaction** of the site, **roaching** and testing soils for suitability (e.g., weeds, texture).[98,99]

7.2.1.4 Potential Long-Term Environmental Effects

Potential long-term environmental effects that must be planned for where the pipeline is abandoned-in-place include: [98,99,100,103]

- **subsidence** arising from eventual corrosion and collapse of the pipe;
- perforated pipe acting as a conduit for water and other substances; and
- pipe exposure through **scouring** in **watercourses**, buoyancy in wetlands, **frost heave** and reduced **depth of cover**.

Soil Subsidence

This condition may arise after operating companies remove **cathodic protection**. Segments of the pipe that are abandoned-in-place will undergo pitting corrosion, which may eventually weaken the pipe to the point of collapse.[103] Det Norsk Veritas (DNV) (2015) predicts that although highly variable, the resulting **subsidence** would typically be expected to be less than 10 cm.[103]

Subsidence may affect some land uses (e.g., agriculture) or **infrastructure** (e.g., roads and railroads). **Subsidence** at road crossings can be mitigated by plating and filling the pipeline under the crossing, using concrete, fillcrete or other suitable material.[98,99]
In other areas, **subsidence** may be managed through natural soil forming processes (e.g., soil development and associated vegetation growth) or normal agricultural operations. If ground **subsidence** becomes problematic, it may be mitigated by adding fill (e.g., soil from the **trench**) or topsoil to affected areas.

Contamination Purge

To mitigate the potential for contamination purge, BAT include:

- cleaning the pipeline before abandoning it, whether abandoned-in-place or removed; [98,100,104] and
- conducting environmental site assessments to support planning for contamination containment and removal.

Potential contaminants (e.g., **PAHs**) derived from the breakdown of pipe coatings following abandonment have low solubility in water, **sorb** to soil carbon and can be broken down over time by soil microorganisms.[105] As a result, it is unlikely that contaminants leached from pipe coatings will move in conduits, in association with water flow.[105]

The pipeline may perforate through corrosion, potentially creating conduits that could locally divert surface water or shallow **groundwater**.[98,100] Conduits may also result in flooding and **erosion**.[99]

Strategies to mitigate potential contamination to surface water or shallow **groundwater** include:

- segmenting the pipeline through cutting and capping;
- plating at strategic locations, such as road crossings, near shallow **groundwater** features or top of slopes; or
- installing plugs.[98]

Considerations for locating planned segmentation or plugs are:

- appropriate spacing;
- local terrain;
- shallow **groundwater**;
- surface water features; and
- environmentally sensitive features. [98,99,100]

Pipeline Exposure
Although there is some risk of pipeline exposure in **watercourses** from **scouring** following abandonment, leaving the pipeline in place is still generally preferred as this will avoid further disturbance to the beds and banks of **watercourses**.[99] Where required, pipelines may be pulled from under **watercourses** to avoid disturbing **riparian** areas and the **watercourse** itself.[100]

Pipe exposure may also occur in wetlands once the pipe is purged of product and if buoyancy control mechanisms, such as swamp weights, are no longer effective.[99] Still, leaving buoyancy control mechanisms in place will reduce the potential for exposure. Although **frost heave** is a documented potential concern related to abandonment in place, pipe exposures as a result of **frost heave** are not frequently reported in the literature.[106] BAT related to pipeline exposure in the context of pipeline abandonment includes:

- reviewing the pipeline ROW for areas where operating companies have previously observed **geohazards**, such as steep slopes, or which have the potential to result in pipeline exposure; and
- considering **erosion** control measures and/or monitoring for these areas.

7.3 Environmental Impact of Recycling and Disposing of Pipelines

Little information is available on the potential effects of recycling or disposing of used pipe, apart from information from DNV (2010) that is provided in the following list.[100]

- Where hazardous substances are detected, the pipe is handled according to the applicable hazardous substance protocols.
- Wrapping a pipe containing coating materials (specifically coal tar wrap) with plastic wrap before removing it can reduce flaking and deposition of the material on the ground.

7.4 Station Sites and Pipeline ROW Reclamation

The NEB expects that provincial reclamation criteria and associated reclamation assessment practices designed to meet such criteria will also apply to NEB-regulated projects.

7.4.1 Reclamation Interventions on ROW

Significantly, many ROWs were seeded after construction with agronomic species and are maintained in a grass-dominated state by mowing, which may suppress natural succession and colonization by native species. Although ROW maintenance, including vegetation management, typically ceases as part of abandonment, vegetation on the abandoned ROW may not readily revert to pre-construction conditions without intervention, such as tree planting or transplant of shrub cuttings such as willows.

7.4.2 Reclamation for Facilities

Above-ground facilities and any section of the pipeline that the operating company intends to remove are reclaimed by:

- removing **infrastructure;**
- remediating any contamination; [*]
- contouring and re-establishing natural drainage patterns; and
- replacing stored topsoil and revegetation.

Emerging technology for reclamation can be found in section 4.2.11.2 (Reclamation Techniques).

[*] See section 6.2.10 (Assessment, Remediation and Monitoring of Contaminated Sites).

8.0 ENGAGEMENT SURVEYS

The NEB consulted with industry members and associations, other governments and academia to acquire perspectives on BAT and emerging technology in the Canadian pipeline industry. Part of the survey included questions on how technology incorporates into operations.

The Online Survey had two Phases[*]:
Phase one*:* questions on pipeline construction, materials, emerging technology and emergency management.
Phase two*:* questions on environmental considerations and emergency management.

The surveys also asked respondents:

- to describe barriers relating to technological uptake; and
- their opinions on regulatory bodies' and industry's role in developing and disseminating BAT info.

Examples of Phase One Survey Questions

1. What are the most effective pipeline technologies being used by one's company in construction, materials, pipeline safety or emergency response?
2. Why are these technologies effective and beneficial?
3. Which factors (economic, social, cost/benefit or regulatory) impact whether or not to implement a technology? What did the testing phase look like?
4. What technological gaps could be improved in pipeline safety, environmental protection/emergency response?
5. What are the most significant barriers (e.g. economic, regulatory) to acquiring technology?
6. What are some examples of emerging technological trends

Phase two survey questions were adapted from phase one survey questions.

Examples of Phase Two Survey Questions

1. What are the most important environmental considerations and emergency management considerations across the lifecycle of a pipeline?
2. For each consideration, what are the most effective technologies?
3. Why is each technology effective? (e.g., what is the added value over other technologies? What is the most significant benefit of each one?)
4. Are you aware of any emerging technologies for the considerations you identified?
5. Which factors (economic, social, cost/benefit or regulatory) decide whether or not to implement a technology?
6. In your opinion, what role does the regulator currently play in developing and disseminating knowledge related to best available technologies in federally-regulated pipelines? What role should the regulator play?
7. In your opinion, what role does industry play in developing and disseminating knowledge related to best available technologies in federally-regulated pipelines? What role should industry play?

[*] 35 survey one respondents; 43 survey two respondents.

Engagement Survey Results Summary

In summary, results demonstrate that incorporation of new technology into pipeline systems can be a lengthy process as introducing new technology requires cost/benefit analysis and demonstration to the pipeline regulatory agency that safety to people and the environment will be maintained or improved. This includes completion of required product testing and pilot or field trials.

A prominent theme among survey responses was description of equipment and best practices regarding leak and spill prevention and response planning. Respondents' focus on incident prevention is understandable as incidents can result in significant human, environmental, and financial costs. Respondents also described the importance of improved information-sharing with regard to BAT. This includes development and dissemination of BAT and emerging technology. Although differences of opinion existed regarding who should lead this initiative (i.e., regulatory versus industry), it is clear that identifying and disseminating this type of information is a collaborative effort that requires the involvement of multiple stakeholders. See Appendix C for table summaries of survey responses.

9.0 CONCLUSION

This report provides an overview of BAT and emerging technologies in federally-regulated pipelines. It focuses on BAT as it relates to environmental considerations, materials, construction and emergency management. As mentioned, it is a snapshot of technology in the year the NEB developed the report. Stakeholders must continue to be informed as technology advances.

Using New Technology Successfully

Implementing new technology successfully depends on a combination of factors, including cost-benefit and meeting regulatory guidelines. It is critical to understand technology in the context of company values, practices, policies, procedures and skills. Technology is most successful when it is implemented through management and employee practices.

Time Required to Implement

Our survey results showed that incorporating new technology into pipelines can be a lengthy process. New products require testing, piloting and field trials, and companies must analyze costs and benefits. Both the operating company and the regulator must conclude that the technology does not compromise safety and environmental performance, or may even improve it.

Respondents' Concerns

Many respondents focused on BAT for leak and spill prevention and response because such incidents can result in significant human, environmental and financial cost.

Respondents wanted better BAT information-sharing, development sharing and dissemination. There were differences of opinion about who should lead this initiative (i.e., regulators or industry), but it is clear this would require collaboration among multiple stakeholders.

Minister
of Natural Resources

Ministre
des Ressources naturelles

Ottawa, Canada K1A 0E4

Mr. Peter Watson
Chair and Chief Executive Officer
National Energy Board
517 Tenth Avenue South West
Calgary, Alberta T2R 0A8

Dear Mr. Watson:

Further to discussions with you and your staff, I am writing to seek guidance, through study and a subsequent report, on the application of "best available technologies" used in federally-regulated pipeline projects. This is an initiative that I announced in May 2014 as part of new world class pipeline safety measures, but for which no amendments to the *National Energy Board Act* are required.

The Government of Canada recognizes the need for dialogue and information on the use of best available technologies for pipelines, which take into account new innovations to continuously improve pipeline safety. I note that, with the National Energy Board's (NEB) recently announced 'Listening to Canadians' tour, the NEB is well-positioned to connect and convene discussions with experts and other stakeholders with relevant expertise to help shape the study in this area.

I firmly believe that technology can and will ensure safer pipelines and protection of the environment. I also believe that guidance from the NEB regarding how companies use best available technologies and how new technologies are being developed, tested and implemented to meet demands for safer pipelines will contribute towards achieving these important goals. The study should consider the economic feasibility for companies operating pipelines to implement the technologies in the construction and operation of pipelines.

Canada

Some of the areas of focus the NEB should examine in its study and report on best available technology include:

- construction methods;
- materials;
- emergency response techniques; and,
- emerging technological developments.

It is expected that the NEB will need to consult and convene discussions with stakeholders, including industry, associations and academia, with relevant technical expertise and knowledge to develop a final study that can be disseminated broadly and contribute to the safety of pipelines and protection of the environment in Canada.

It is through subsection 26(2) of the *National Energy Board Act* that I am making this request. I would ask that the NEB undertake this study and provide the report to me by March 31, 2016. Such a timeline will provide the opportunity to consult with relevant stakeholders. As this matter falls under the Board's expected operational requirements from time to time, no additional funding will be allocated to the Board for this request.

Thank you for your attention to this matter. I look forward to receiving the NEB's study with respect to the application of best available technologies in federally-regulated pipeline projects.

Sincerely,

The Honourable Greg Rickford, P.C., M.P.
Minister for Natural Resources Canada and for the
Federal Economic Development initiative for Northern Ontario

Minister
of Natural Resources

Ministre
des Ressources naturelles

Ottawa, Canada K1A 0E4

AVR
APR 1 9 2016

Mr. Peter Watson
Chair and Chief Executive Officer
National Energy Board
517 Tenth Avenue SW
Calgary, Alberta T2R 0A8

Dear Mr. Watson:

I am writing to you in follow-up to correspondence sent to you by my predecessor in February 2015. In his letter, my predecessor requested that you study and provide a report on the application of best available technology used in federally-regulated pipeline projects.

I am writing to convey my interest in this study and report. As you are aware, part of our Government's platform is a commitment to modernize the National Energy Board. We have also committed to review Canada's environmental assessment processes and introduce a requirement for project advocates to choose the best technologies available, with the goal of reducing the environmental impacts associated with resource projects. I consider that the study you are currently undertaking on the application of best available technology will support both of these commitments, ensuring safer pipelines, environmental protection, and increased public confidence in regulatory processes.

In the original letter, it was requested that you submit your report by March 31, 2016. I would like to offer the Board an additional six months (i.e., to September 30, 2016) to work on the study and report, to ensure both adequate time to engage with stakeholders as well as a more robust study of best available technologies for pipelines including:

- Construction methods;
- Materials;
- Emergency management techniques;
- Emerging technology developments; and
- Environmental considerations.

I look forward to receiving the Board's assessment of how new technologies are being developed, assessed and implemented to achieve the objective of safer pipeline operations. Economic considerations that may influence industry's development and use of best available technology will also be an important consideration.

Thank you for your continued work on this important file.

Yours sincerely,

The Honourable Jim Carr, P.C., M.P.

APPENDIX C

Table 1: Phase One Survey Results

Technologies in Construction, Materials, Pipeline Safety & Emergency Response (Survey One)	
General Comments	• Monitoring stress corrosive cracking (SCC) is important • Technology must satisfy economic and regulatory limitations, not just testing, integration and reliability
Best Available Technology	• In-line inspection (ILI) • Non-destructive evaluation (NDE) of pipeline • Inspection data • New pipe material that prevents corrosion
In-Line Inspection	• Effective because it is very precise • More effective than direct assessments or hydrostatic testing
Factors Affecting Implementation of New Technology in Order of Importance	• Cost/benefit analysis • Regulatory • Economic • Social
Testing New Technology	• Field trials to validate • Pilots or lab tests that replicate realistic environment and operational conditions • Better to have vendor testing data before pipeline company conducts its evaluation
Technology With Gaps or That Needs Improvement	• Leak detection • Spill containment • Spill clean-up • ILI tool accuracy • ILI tools for 'un-piggable' pipelines • Small leak detection (< 5 barrels) • Detection of GHGs from pipelines and facilities
Emerging Technology	• Leak detection (did not specify) • Spill containment (did not specify)

Environmental Considerations (Survey Two)

Critical Concerns	• Preventing leaks and spills • Responding to leaks and spills • Pipeline design and pre-construction is an important phase that entails appropriate assessment and mitigation planning, followed by implementation and monitoring • Pipeline impact on water bodies, including watercourse crossings and water quality • Waste disposal techniques, especially hazardous waste and pipeline abandonment • Air emissions from pipeline construction and operation (including facilities)
Best Available Technology for:	
Leak Prevention and Response Measures	• Routine monitoring (line patrol) and shut down • Fiber optics • Depth of cover • ILI • External pipe inspection (e.g. NDE) • Cathodic protection (CP)
Design and Pre-construction	• Trenchless construction • Topsoil management and backfilling • Reclamation procedures • Herbicides and equipment washing to control spread of invasive species • Pipe material and coatings • Welding procedures • Biometric pipeline repair procedures • Line patrol, including aerial video
Pipeline Impact on Water Bodies	• Horizontal direction drilling (HDD) • Field analysis techniques • Watercourse monitoring • Leak detection • Trenchless installation of pipe • Environmental protection planning • Construction timing • Sensitive species breeding windows • GIS and aerial/satellite imagery • GIS mapping • Light detection and ranging (LiDAR) • Pipeline material (high-quality steel) • Spill management procedures

Waste Disposal Techniques	• Computer-based waste tracking programs • Recycling of materials (e.g., pipeline coating) • Removal of contaminated soil • Pipe abandonment in place • Awareness and understanding of the impact of abandoning pipe in place versus removal
Management Strategies for Air Emissions	• Carbon capture storage and use • High quality steel • Active monitoring of pipelines

Table 3: Phase Two survey results: Emergency Management

Emergency Management (Survey Two)	
General comments	• Having well developed and practised emergency response plans is crucial • Important areas include: forest fire plans, traffic management, evacuation planning, impact on residents, and impact on the environment • Sharing industry knowledge on emergency management is crucial to inform industry's risk management practices.
First responders—key factors	• Adequate training • Regular communication with first responders
Pipe issues	• Regular inspections of pipes • Protection factors such as depth of bury, and pipe material and coating • Valve placement • Resources to detect issues and their location • Best technology for design/construction: high strength steel, block valves and bonded coatings

Best available technology for spill planning and response	• GIS mapping and flow modelling
	• Line patrol technologies, such as aerial surveillance and infrared technologies
	• Fast flowing water booms and skimmers
	• Communication technology
	  • for training, such as WebEx software
	  • for mass communication during an emergency
	  • One Call/Click Before You Dig initiative
	• High-velocity vacuum pumps
	• Damage prevention programs

Technology areas that need improvement or development	• Backfilling techniques
	• Water treatment systems
	• Understanding modern geologic processes and their potential to impact pipeline integrity over time
	• Alternative power sources for remote operations
	• Aerial HD video based on GPS—to monitor revegetation crop growth, drainage issues and wetland restoration
	• Monitoring (ILI and NDE advancement)
	• Data refinement of existing leak detection systems:
	  • improved analytics and statistics
	  • additional instrumentation on most pipelines, such as additional flow meters, pressure and temperature transmitters at facilities along the pipeline
	  • satellite imaging of fugitive emissions and advancements in ability to quantify this information
	• High strength steel performance
	• Weld modelling
	• Techniques to assess coating performance and its interaction with

	Cathodic Protection
Barriers affecting technology uptake	• Mitigation effectiveness (safety of people and the environment) • Economic feasibility • Regulatory compliance—constraints on use • Social impacts (e.g., landowner concerns) • Staying aligned with changing policy in multiple jurisdictions • Properly testing and validating • Commercial availability • Accessing information on new technology
Strategies for keeping up-to-date	• Trade shows • Industry association publications • Professional networks (CEPA, the American Petroleum Institute (API), and the Association of Oil Pipe Lines (AOPL) • Workshops and conferences • Regulator-shared information • Inter-company sharing of lessons and best practices • In-house research, development, and innovation that benchmarks with other companies
Regulator's role in developing and disseminating	• Some comments that regulator maintains separation with industry for impartiality, which may be hindering communication • Industry may be fearful of requesting information from regulator since regulator has enforcement role • Others stated regulator promotes stakeholder interaction through annual forums (e.g., the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA)) • Small number said limited or no dissemination
How should regulator be involved in developing and disseminating	• More face-to-face interactions • Review regulations to ensure they promote BAT • Understand and support that BAT should be economically viable • Clear guidance and endorsement of new and best technology • Make information available through electronic mediums, conferences, workshops and trade shows • Share successful implementation with industry • Small number said regulator should have minor or no role
Industry's role in developing and disseminating	• Participation with organizations (e.g., CSA, CEPA) • Joint industry involvement with subject matter experts in companies who collaborate and share • Participate in and fund research • Reports, tradeshows, conferences for information from associations, vendors, consultants

Ideal role of industry in Emerging Technology	• Continue to develop and share information through associations • Continue to seek and assess BAT • Engage in outreach to promote industry improvement • Engage with public and media to hear concerns and proactively develop new technology and information • Support field testing • Use new technology wherever practical
Who should develop and disseminates information on BAT and emerging technology	• Industry • Regulator • Industry and Regulator as partners

LIST OF ABBREVIATIONS

AIV	Alternative Integrity Validation
AOPL	Association of Oil Pipe Lines
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ATV	all-terrain vehicle
BAT	best available technology
BACTEA	best available control technology economically achievable
BLIERS	base level industrial emission requirements
CAPP	Canadian Association of Petroleum Producers
CEAA	Canadian Environmental Assessment Act
CEPA	Canadian Energy Pipeline Association
CISEC	Certified Inspector of Sediment and Erosion Control
CMS	computational monitoring systems
CO_2	carbon dioxide
COP	common operating picture
CP	cathodic protection
CPESC	Certified Professional in Erosion and Sediment Control
CPM	computational pipeline monitoring
CPTC	Canadian Pipeline Technology Collaborative
CSA	Canadian Standards Association
DA	direct assessment
DNV	Det Norsk Veritas
EA	environmental assessment

EAS	environmental alignment sheet
EMAT	electromagnetic acoustic transponder
EPP	environmental protection plan
EPRI	Electric Power Research Institute
ESA	environmental and socio-economic assessment; environmental site assessment
FAD	failure assessment diagram
FEED	front end engineering design
FEM	finite element methodology
GAC	granulated activated carbon
GHG	Greenhouse Gas
GIS	geographic information system
GPS	Global Positioning System
HDD	horizontal directional drilling
HDPE	high-density polyethylene
HLAW	hybrid laser arc welding
ICS	Incident Command System
IEAGHG	International Energy Agency Greenhouse Gas
IFRT	internal floating roof tank
ILI	in-line inspection
LDAR	leak detection and repair
LED	light-emitting diode
LiDAR	light detection and ranging
LNAPL	light non-aqueous phase liquid
MFL	magnetic flux leakage

MOC	management of change
MSARP	multi-sector air pollutant regulations
NDE	non-destructive evaluation
NEB	National Energy Board
NEBA	net environmental benefit analysis
NEB Act	National Energy Board Act
NEB DPR	National Energy Board Damage Preventions Regulations – Authorizations
NO_X	nitrogen oxide and dioxide
NPS	nominal pipeline size
OEB	Ontario Energy Board
OPR	Onshore Pipeline Regulations
PAH	polycyclic aromatic hydrocarbon
PCMP	post-construction monitoring program
PDAM	pipeline defect assessment manual
PHMSA	Pipeline and Hazardous Materials Safety Administration
PICA	Pipeline Integrity Crack Assessment
QA/QC	quality assurance and quality control
QRA	quantitative risk assessment
RAP	restricted activity period
ROW	right-of-way
RT	radiographic
RTP	reinforced thermoplastic pipe
SARA	Species at Risk Act
SCADA	supervisory control and data acquisition

SCC	stress corrosion cracking
SECP	sediment and erosion control plan
SIMA	spill impact mitigation assessment
SPME	solid phase micro extraction
STA	spill-treating agents
TAPS	Trans Alaska Pipeline System
TEK	traditional ecological knowledge
TSB	Transportation Safety Board
TU	traditional use
UAV	unmanned aerial vehicle
UT	ultrasound
UV	ultraviolet
VOC	volatile organic compound
VECs	valued environmental components
VSCs	valued socio-economic components
X-ray	radiographic inspection

GLOSSARY

abandonment	the processes and actions a company takes at the end of the life of a pipeline or facility to obtain approval from the regulator to abandon the pipeline or facility
acid rock drainage	acid formed by relatively common minerals when they are exposed to water and air
admixing of soils	unintentional mixing of topsoil and subsoil during soil handling
adsorb	to hold molecules as a thin film on the outside surface or on internal surfaces within the material
aggregate	a material formed from a loosely consolidated mass of fragments or particles
agronomic mixes	seed mixtures composed of plant species or varieties developed for agricultural purposes
air sparging	injecting pressurized air into ground water that has been contaminated by volatile organic compounds, for example petroleum hydrocarbons, to remove the contaminants
alternative integrity validation	an enhanced QA/QC process that provides equivalent reliability as a pressure test (hydro test)
alluvium	a deposit of clay, silt, sand, and gravel left by flowing streams in a river valley or delta
ambient	relating to the immediate surroundings
amine regenerators	processes that remove hydrogen sulfide and carbon dioxide, referred to as "sweetening" because the door of the processed products is improved by the absence of hydrogen sulfide

amphibious track-based vehicles	a tracked vehicle that can operate on both land and water
anionic polymer	substance used to bind together soil to reduce erosion potential
armouring	applying a protective covering, (e.g., rocks, vegetation or other materials) to protect stream banks
attenuation	a reduction of an effect
backfill	material used to refill an area that has been excavated
backfilling	the process of filling the trench where a newly constructed or recently unearthed pipeline is located
bedrock	solid rock underlying soil
berm	an artificial ridge or embankment
bioremediation	the use of microorganisms or other life forms to clean up a polluted site
biosolids	organic matter recycled from sewage
block valves	a valve installed in a pipeline that can block the flow of oil or gas through the line.
blowdown	using pressure to remove solids or liquids from a container or pipe
bonded fiber matrix	a continuous layer of long fiber strands held together by water-resistant glue
booms	temporary floating barrier used to contain an oil spill

boring	mechanical trenchless pipeline crossing method that does not use a mud system, often used to construct road or rail crossings
bucket wheel	see glossary definition for wheel trencher
carbon capture and sequestration	a process that captures carbon dioxide and stores it in a deep geological formation
carbon footprint	the amount of carbon dioxide and other carbon compounds emitted by a particular person, group, etc. due to the consumption of fossil fuels
cathodic protection (CP)	a technique used to control the corrosion of a metal surface by connecting it to a metal that is more easily corroded
channel substrate	natural material found along the bed and banks of a flowing water body
clear-span	single span bridge from bank to bank with no support structures in the stream channel
coffer dam	a watertight enclosure that is pumped dry for construction work below the waterline
compaction	the process by which soil is compressed by the weight of overlying sediment or by mechanical means
compaction wheels	heavy equipment used to put downward pressure on replaced soils during pipeline clean-up to secure material in place
cut-blocks	specific areas with defined boundaries, authorized for harvest
dam and pump	the process by which a dam is placed in a stream channel to prevent the main flow of water from flowing through the disturbance area within the stream channel. Water is pumped from the upstream side of the excavation to the downstream side

	to bypass the in stream construction area
delivery terminal	the end point of a pipeline
depth of cover	the vertical distance from the top of the pipe to the ground surface when a pipe is buried underground
desktop reviews	studies conducted using existing information sources only, often done prior to site visits
dewatering	the removal of water from solid material or soil
direct pipe	a crossing technique that allows pipe sections to be installed directly in a single step during trenchless crossing construction
dispersant	substance added to a suspension to prevent settling or clumping
ditch and spoil	the practice of digging a trench and placing the removed material beside the trench in a pile to be used as back-fill in that location after construction
ditch plug	material placed in the bottom of a pipeline trench to prevent the water from flowing along the trench
diversion ditches	small excavations that divert overland water flow away from exposed slopes
drilling string	a column of drill pipe that transmits drilling fluid and torque to the drill bit
engineered soil	mulch and soil mixed with seed sprayed along disturbed areas to help with reclamation
environmental constraints	any environmental limitation on routing or siting options. Includes no-go areas and also areas where construction may be affected by timing constraints, or may incur higher mitigation

	costs
environmental protection plans (EPP)	documents created primarily to guide construction contractors regarding environmental features and mitigation commitments
erosion	the process of eroding or being eroded by wind, water, or other natural agents
erosion control blankets	pre-formed protective blanket of plastic fibers, straw etc. designed to protect soil from the precipitation and overland flow, and to retain moisture to help establish vegetation
fauna	the animals of a particular region or habitat
feedstock	raw material that supplies or fuels a machine or industrial process
fescue	narrow-leaved grass
fiber optic	the transmission of information as light impulses along a glass or plastic wire or fiber
finishing blades	heavy equipment used to move soil for contouring during pipeline clean up
finite element methodology (FEM)	computer analysis of the load-bearing capacity of complex pipeline components or of components under complex loadings by representing the components as an assemblage of simpler sub-elements
flaring	burning natural gas at a facility site
floating roof tank	a storage tank with a roof that floats on the surface of the stored liquid, commonly used to store large quantities of petroleum products such as crude oil
flocculation	a mixing technique that assists in the settling of particles

flora	the plants of a particular region or habitat
flume	large pipe through which water from the upstream side of a dam flows downstream of the work area
frost heave	freezing causing expansion and the uplift of water-saturated soil or other surface deposits
fugitive emissions	emissions of gases or vapours from pressurized equipment caused by leaks
gas turbine compressor	gas powered turbine system that maintains pressure and flow of product in the line
geographic information system (GIS)	system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data
geogrid	geosynthetic material used to reinforce soils and similar materials
geohazards	geological and environmental conditions and long-term or short-term geological processes that may lead to widespread damage or risk
geotechnical	relating to practical applications of geological science
geotextile	permeable fabrics which are used with soil to separate, filter, reinforce, protect, or drain
greenfield	previously undeveloped sites available for commercial development or exploitation
greenhouse gas	a gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide and chlorofluorocarbons

ground-based line patrol	inspection on foot or, in some cases, by automobile
groundwater	water held underground in the soil or in pores and crevices in rock
grubbing	removal of the tree stumps and surrounding root mat during pipeline construction in a forested landscapes
harrow	an implement consisting of a heavy frame with teeth or tines that is used on ploughed soil to break up clods, remove weeds, and cover seed
hibernacula	places in which a creature seeks refuge, such as a bear using a cave to overwinter
holiday detector	an electro-static wand contoured to the pipe diameter, that detects coating defects (also known as holidays) when passed over the pipe
horizontal directional drilling (HDD)	trenchless method of installing underground pipe that uses a mud-based system to maintain circulation around a drill bit
hot tapping	a method of making a connection to existing piping or pressure vessels without having to empty that section of pipe or vessel (this means that a pipe or tank can continue to operate)
hydro mulching	a planting process that uses a wet mixture of seed and mulch instead of dry seed. Hydro mulching is used on construction sites as an erosion control technique
hydrocarbon	a compound of hydrogen and carbon; the chief components of petroleum and natural gas
hydrostatic test	a test in which a pipeline is filled with water and pressurized to exceed maximum operation pressure to reveal any defects in the pipeline or the welds

impoundments	a body of water which is confined within an enclosure, for example, a reservoir
IMU tool	An inline inspection tool that contains a gyroscopic Inertial Measurement Unit capable of determining the profile of a pipeline in three dimensions
infrastructure	the physical structures and facilities (e.g., buildings, roads, etc.) needed for the operation of a pipeline
inoculation	the introduction of a micro-organism into a medium
interceptor dikes	a road construction feature that reduces flow lengths to prevent erosion on sloping roads, cleared paths through woodland or other access ways
invasive species	a non-native plant, fungus, or animal species which has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health
isolation valves	valves for isolating branch lines, stations, pressure-relieving installations, and other facilities
leaching	natural process by which water soluble substances (such as calcium, fertilizers, pesticides) are washed out from soil or wastes
leks	assembly areas where wildlife such as grouse display courtship behaviour
levelling	creation of a sufficiently flat and even surface to meet construction and/or operational needs
LiDAR	(Light Detection and Ranging) a surveying technology that illuminates a target with a laser light to measure distance
line-bending	process by which sections of pipe are bent to conform to the

	planned route
line patrols	visual inspection of a pipeline to identify potential abnormalities
logging decks	sites for storing salvaged timber cleared during construction
louvers	openings with angled slats used to reduce mechanical equipment noise transmitted through building openings
low-drift IMU	a gyroscopic device with low gyroscopic drift fitted to an ILI tool that plots pipeline profile
low impact pipelining	construction of pipelines using techniques and equipment that minimize impacts to the landscape
maternity roosts	warm, safe places where bats gather to rear young. Some groups of bats return to the same maternity roost site every year
methane	a colorless flammable gas that has no smell and that can be burned for fuel
microtunneling	a digging technique that uses a remotely operated microtunnel boring machine to construct small diameter tunnels
mitigation	reducing the probability or severity of an effect
mounding	a pile of earth, gravel, sand, rocks, or debris heaped for protection or concealment
nitric oxide	a colorless poisonous gas that is present in the atmosphere and is a product of hydrocarbon combustion
nitrogen dioxide (NO_2)	a poisonous gas, present in untreated automobile exhaust, that is an air pollutant

nurse crop	an annual crop used to help establish a perennial crop
offsetting	improving areas away from a project for use as off-site restoration, land securement, conservation, population management measures, and in-lieu payments
optical gas imaging	a thermal imaging technique used to detect gas leaks and fugitive emissions
ovalization	the making of the circular cross section of the pipe oval-shaped due to external force or other effects
overstripping	removal of soil layers to below topsoil layer depth during site preparation
piling	structural support comprised of a length of wood, steel, or other construction material
pipeline weights	material used to control buoyancy of sections of pipeline that are routed through wet areas or watercourses
pipe mill	the factory where pipe is manufactured
polychlorinated biphenyl	a group of man-made compounds that were widely used in the past, but which are banned in many countries because of environmental concern
polycyclic aromatic hydrocarbons (PAH)	a group of over 100 different chemicals that can be harmful to human health under some circumstances
polymer	a substance made up of a large number of smaller molecules that link together to form larger molecules
processing plants	facilities that clean raw natural gas by separating impurities and various non-methane hydrocarbons and fluids to produce pipeline quality natural gas

project footprint	the area of land disturbed during construction of a project
punching	a method of trenchless pipeline crossing where the casing or pipe is pushed or rammed under the watercourse or other crossing
quantitative metrics	parameters or measures of quantitative assessment used for measurement, comparison or to track performance or production
receptor	an individual, population, or location that may be affected positively or negatively by a project
reclaim	to return land to a state that is functionally equivalent to pre-development conditions in terms of the range of land uses it can support
remediation	remedying something that is undesirable or deficient
restricted activity period (RAP)	designated sensitive times of the year when development activities should be avoided or modified to mitigate impacts to environmental features of concern
revegetate	introduce a new growth of vegetation on disturbed or barren ground
ridge vent	acoustic building design feature used provide ventilation and to re-direct and reduce mechanical equipment noise transmitted through building openings
rig mat	a portable platform used to support equipment used in construction and other resource-based activities. May also be used to provide passage over unstable ground, pipelines and more
right of way (ROW)	the area of the project footprint where the pipeline will be located

riparian	of, relating to, or situated on the banks of a wetland or water body
rippers	construction or agricultural equipment used to tear and rip soil (especially compacted or frozen materials)
roaching	the practice of creating a crown of backfilled material on top of a pipeline trench to prevent sinking or subsidence as the trench fill material settles and compacts
rollback	the practice of spreading available woody debris flat on the ground over disturbed areas
root mat	established root system of vegetation, anchoring soil layers and providing stabilization
root pass	the first line of weld laid down when joining two parts (such as two pipe joints) using a multi pass welding procedure, the last pass being known as the cap
scalping	removal of or damage to the sod layer in grassland or native vegetation areas
scouring	removal of material from a watercourse bank or bed due to high velocity flow or turbulence
sectionalizing valves	mainline valves used for isolating a segment of a pipeline
sediment	material (such as stones and sand) that is carried into water by water, wind, or disturbance around a water body; matter that settles to the bottom of a liquid

sediment basins	temporary pond built on a construction site to capture soil that is washed off during rain storms, and protect the water quality of a nearby stream, river, lake, or bay
set-back	the absolute minimum distance that must be maintained between any energy facility (for example a pipeline, or a gas plant) and a dwelling, rural housing development, urban centre, or public facility
sheet piling	an earth retention and excavation support technique that retains soil, using steel sections with interlocking edges
silt	fine sand, clay, or other material carried by running water and deposited as a sediment, especially in a channel or harbour
silt fence	temporary sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment (loose soil) in storm water runoff
sinking skirt	skirt attached to a boom that rides below the surface and prevents the oil from being pushed under the booms
slack flow/slack line flow	a flow condition in liquid pipelines that develops vapor bubbles at points at which the pipeline pressure falls below the vapor pressure of the liquid
slope breakers	structures that limit erosion on rights-of-way
slumping	movement of material (such as soil, sand, or rock) that occurs when rock layers move a short distance down a slope.
oil amendments	materials which are worked into the soil to enhance the soil's properties.
soil horizons	a layer of soil whose physical characteristics differ from the layers above and beneath. Horizons are defined by physical

	features, like colour and texture
soil matrix	the combination of solids spaces containing liquids or gases in a soil
solid phase micro extraction	(SPME) a solvent-free extraction technique used in environmental analysis to detect the presence of pesticides, phenols, PCBs, PAHs, etc., and to a lesser extent, inorganic compounds
sorb	take up a liquid or a gas either by adsorption or by absorption
spoil pile	temporary storage area for extraneous construction material and vegetation removed from the ROW during brushing
staging area	resting and feeding places of migratory bird species or areas where equipment is kept prior to use
straw crimping	a layer of straw or hay spread or blown over seeded and fertilized soil to protect the soil's surface
strain-based design	a design methodology in which certain load types associated with buried pipelines (e.g. combination of ground movement and thermal) are allowed to produce strains in the pipeline that cause permanent deformation, thereby utilizing a fuller range of steel load-bearing capacity than can be achieved by more conventional, stress-based design
stress corrosion cracking (SCC)	cracking induced by the combined influence of high and/or varying tensile stress, a corrosive soil environment, and susceptible pipe coatings
stripping	removal of topsoil during site preparation
subaqueous	taking place underwater
subsidence	the gradual caving in or sinking of an area of land

subsoil	the soil lying immediately under the surface soil
subsoil plough	an implement that breaks up soil at depths below the limit of a traditional plough
surficial	the surface layer
tank farms	industrial sites containing steel tanks for the storage of oil or other liquid petroleum products
terminals	storage facilities at each end of a transmission pipeline that receive product from feeder lines for transmission or receive product from transmission lines to be routed for distribution or other modes of transport
trench breaker	barriers placed within an open pipeline excavation in order to slow flow and reduce erosion in the trench and also to prevent the trench from becoming a subsurface drainage path
trenched watercourse crossing	a method of pipeline crossing where an open trench is used to construct through a watercourse in dry, frozen, or flowing conditions
trenchless watercourse crossing	a crossing method in which there is no disturbance to the bed and banks of a waterbody
upset events	a disruption to normal designed operating conditions, typically requiring prompt corrective action
turbid	(liquid) that is cloudy, opaque, or thick with suspended matter
ungulate	a mammal with hooves
unmanned aerial vehicle (UAV)	aircraft piloted by remote control or onboard computers

vapour recovery	recovering the vapours of hydrocarbons so that they do not escape into the atmosphere
venting	the direct release of natural gas to the atmosphere
volatile fraction	the quantity of a substance that can evaporate under normal atmospheric conditions
volatile organic compounds (VOC)	organic chemicals that can evaporate under normal atmospheric conditions
washout	precipitation or flooding causing the sudden erosion of soil or other material
watercourse	a natural or artificial channel through which water flows
watersheds	an area of land that separates waters flowing to different rivers, basins, or seas
weir	low dam built across a river to raise the level of water upstream or regulate its flow
wheel trencher	a track-mounted wheel with buckets attached to it. As the wheel rotates, the buckets dig soil from the trench

ENDNOTES

1 OSPAR (Oslo and Paris Commission). 2016. Best Available Techniques (BAT) & Best Environmental Practices (BEP). Available at: http://www.ospar.org/about/principles/bat-bep. Accessed July 2016.

2 US EPA (United States Environmental Protection Agency). 2016. BAT. Available at: http://www.epa.ie/licensing/info/bref/. Accessed July 2016.

3 European Union. 1996. Council Directive 96/61/EC Integrated Pollution Prevention and Control. Available at: http://www.eea.europa.eu/policy-documents/council-directive-96-61-ec-ippc. Accessed July 2016.

4 AMEC (AMEC Earth and Environmental). 2009. Identification and Mitigation of Acid Rock Drainage and Metal Leaching During Construction, Enbridge Northern Gateway Project. Submitted to Northern Gateway Pipelines Inc. October 2009, revised February 16, 2010. Available at: http://www.ceaa.gc.ca/050/documents_staticpost/cearref_21799/2213/Volume3/Vol_3_Appendix_E-1-2.pdf. Accessed July 2016.

5 OMECC (Ontario Ministry of Environment and Climate Change). 2016. Guideline for identification of Best Available Control Technology- Economically Achievable (BACTEA). Available at: https://www.ontario.ca/page/guideline-identification-best-available-control-technology-economically-achievable-bactea. Accessed July 2016.

6 BC MOE (British Columbia Ministry of Environment). 2015. Factsheet: Waste Discharges Best Achievable Technology. Available at: http://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/pulp-paper-wood/best_achievable_control_tech.pdf. Accessed July 2016.

7 Dr. Ing. Christoph Kalwa, Dr. Ing. Hans-Georg Hillenbrand, Dr. Ing. Michael Graf, High Strength Steel Pipes: New Developments and Applications, Onshore Pipeline Conference Houston Texas, USA, June 10-11, 2002, Print.

8 A. Parvez, A. Sakr, M. Yeats & B. Weller, *Suitability of reinforced thermoplastic pipe in crude oil Containing Aromatic Solvents and additionally Alkaline Liquids for Enhanced Oil Recovery*. Gas & Oil Expo and Conference North America 2011GEOC11-GOXC11-102. Print

9 Canadian Standards Association, CSA Z662-11 (2011) - Oil and Gas Pipelines Systems, Print.

10 BC MFLNRO (British Columbia Ministry of Forests, Lands and Natural Resource Operations). 2014. A compendium of wildlife guidelines for industrial development projects

in the north area, British Columbia. Interim Guidance. 206 pp. Canadian Environmental Assessment Act, 2012. S.C. 2012, c. 19, s. 52.

[11] BC MOE (British Columbia Ministry of Environment). 2013. Implementation plan for the ongoing management of South Peace Northern Caribou (*Rangifer tarandus caribou* pop. 15) in British Columbia. Victoria, BC. 16 pp.

[12] McNay, R.S., D. Cichowski, and B.R. Muir. 2013. Action Plan for the Klinse-Za Herd of Woodland Caribou (*Rangifer tarandus caribou*) in Canada [Draft]. *Species at Risk Act* Action Plan Series. West Moberly First Nations, Moberly Lake, British Columbia. 28 pp.

[13] Environment Canada. 2014. Recovery Strategy for the Woodland Caribou, Southern Mountain population (*Rangifer tarandus caribou*) in Canada. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa. viii + 103 pp.

[14] Golder Associates. 2012. Boreal caribou habitat restoration. Prepared for BC Ministry of Forests, Lands and Natural Resource Operations, Prince George, BC. 24 pp.

[15] COSIA (Canada's Oil Sands Innovation Alliance). 2016. Caribou habitat restoration. Available at: http://www.cosia.ca/caribou-habitat-restoration. Accessed July 2016.

[16] BC MOE (British Columbia Ministry of Environment). 2014. Procedures for mitigating impacts on environmental values (Environmental Mitigation Procedures). BC Ministry of Environment, Victoria, BC. 68 pp.

[17] Petter, T. and Mutrie, D.F. 2009. Environmental Conservation Practices for Pipelines, in Pipeline Engineering, in Encyclopedia of Life Support Systems (EOLSS), Developed under the auspices of the UNESCO, EOLSS Publishers, Paris, France. Available at http://www.eolss.net/sample-chapters/c08/e6-187-10-00.pdf. Accessed July 2016.

[18] NEB (National Energy Board). 1991. Reasons for Decision TransCanada Pipelines Limited GH-1-91. July 1991. Available at: http://publications.gc.ca/collections/Collection/NE22-1-1991-11E.pdf. Accessed July 2016.

[19] OEB (Ontario Energy Board). 2011. Environmental Guidelines for the Location, Construction and Operation of Hydrocarbon Pipelines and Facilities in Ontario, 6th Edition. Available at: http://www.ontarioenergyboard.ca/oeb/_Documents/Regulatory/Enviro_Guidelines_HydrocarbonPipelines_2011.pdf. Accessed July 2016.

[20] Neville, M. 2003. Best Management Practices for Pipeline Construction in Native Prairie Environments. Prepared for Alberta Environment and Alberta Sustainable Resource Development. October 2003. Available at https://www.aer.ca/documents/applications/BestManagementPracticesPipeline.pdf. Accessed July 2016.

[21] Pembina Institute. Undated. Pipeline Construction & Operation - Environment & Energy in the North, A Primer. Available at: https://www.pembina.org/reports/nps_Pipeline.pdf. Accessed July 2016.

[22] CEPA (Canadian Energy Pipeline Association). 2015. Six Pipeline Technologies You'll Want to Know About. Available at: http://aboutpipelines.com/en/blog/6-pipeline-technologies-youll-want-to-know-about/. Accessed July 2016.

[23] Georgia Transmission Corporation (2010). “GTC-EPRI Siting Model.” Available at: https://www.gatrans.com/planning-construction/gtc-epri-siting-model/Pages/default.aspx. Accessed July 2016.

[24] INGAA (Interstate Natural Gas Association of America) Foundation Inc. 1999. Temporary Right-of-Way Width Requirements for Pipeline Construction. Gulf Interstate Engineering. Available at: http://www.ingaa.org/File.aspx?id=19105. Accessed July 2016.

[25] IFC (International Finance Corporation) World Bank Group. 2016 draft. Environmental, Health, and Safety Guidelines-Petroleum Refining. Revised 2016. Available at: http://www.ifc.org/wps/wcm/connect/3a4f9f804c364938a6c1a6d8bd2c3114/Petroleum+Refining+EHS+Guideline+-+2016vs2007+version+in+tracked+changes.pdf?MOD=AJPERES. Accessed July 2016.

[26] Blue Source Canada. 2011. Blowdown Protocol for Pipeline Systems, prepared for Province of British Columbia, April 2011, Final.

[27] IFC (International Finance Corporation). 2007a. Environmental Health and Safety Guidelines for Crude Oil and Petroleum Product Terminals. IFC World Bank Group, April 30, 2007. Available at: http://www.ifc.org/wps/wcm/connect/81def8804885543ab1fcf36a6515bb18/Final+-+Crude+Oil+and+Petroleum+Product+Terminals.pdf?MOD=AJPERES. Accessed July 2016.

[28] Yan, Si Zhi and Chyan, Lee Sheng. 2009. Performance enhancement of BOTDR fiber optic sensor for oil and gas pipeline monitoring, Optical Fiber Technology 16 (2010): 100-109. Available at: http://ac.els-cdn.com/S1068520010000027/1-s2.0-S1068520010000027-main.pdf?_tid=e68a4228-541a-11e6-a0ee-00000aacb362&acdnat=1469638699_158db7cdd91d5e68281019f931fdc1d0. Accessed July 2016.

[29] Genalta Power. 2015a. Waste Heat to Power. Available at: http://www.genaltapower.com/solutions/#waste-heat. Accessed July 2016.

[30] Genalta Power. 2015b. Waste Solution Gas. Available at: http://www.genaltapower.com/solutions/#wastesolution-gas. Accessed July 2016.

[31] Blomquist, Paul. 2010. Hybrid Laser Arc Welding (HLAW). Available at: https://app.aws.org/conferences/newweldingtech/blomquist.pdf Accessed January 2016.

[32] TRCA, 2015 (Toronto and Region Conservation Authority). Horizontal Directional Drill Guidelines.

[33] Tensar. 2016. Oil and Gas. Refining Exploration and Operations in the Oils and Gas Industry. Available at: http://www.tensarcorp.com/Market-Sectors/Oil-and-Gas. Accessed July 2016.

[34] CAPP (Canadian Association of Petroleum Producers). 2004. Planning Horizontal Directional Drilling for Pipeline Construction. Available at: http://www.capp.ca/publications-and-statistics/publications/83652. Accessed July 2016.

[35] Health Canada. (2011). DRAFT: Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise. Environmental Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. Available at: https://www.gov.mb.ca/conservation/eal/archive/2012/summaries/5471_appendix2.pdf Accessed July 2016.

[36] AER (Alberta Energy Regulator). 2014. Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas. Manual 007. April 2014. Available at: https://www.aer.ca/documents/manuals/Manual007.pdf. Accessed July 2016.

[37] Government of Alberta. 2011. Recommended Land Use Guidelines for Protection of Selected Wildlife Species and Habitat within Grassland and Parkland Natural Regions of Alberta. Available at: http://aep.alberta.ca/fish-wildlife/wildlife-land-use-guidelines/documents/WildlifeLandUse-SpeciesHabitatGrasslandParkland-Apr28-2011.pdf. Accessed July 2016.

[38] Stantec (Stantec Consulting Ltd.). 2013. Migratory Bird Convention Act: A Best Management Practice for Pipelines, Draft For Discussion. Prepared for Canadian Energy Pipeline Association. Available at: http://www.cepa.com/wp-content/uploads/2014/01/Migratory-Birds-Sept-26-2013-for-Publication.pdf. Accessed July 2016.

[39] CAPP (Canadian Association of Petroleum Producers). 2014. Beneficial Management Practice to Mitigate Risk of Incidental Take: Upstream Oil and Gas Construction and Development Activities. Environmental Dynamics Inc. Prince George, BC.

[40] AENV (Alberta Environment). 1995. Manual on Soil Conservation and Pipeline Construction – Draft. Based on a report prepared by TERA Environmental Consultants and Pedology Consultants. Available at: https://extranet.gov.ab.ca/env/infocentre/info/library/6857.pdf. Accessed July 2016.

[41] Pettapiece, W.W. and M.W. Dell. 1996. Guidelines to Alternative Soil Handling Procedures During Pipeline Construction. Prepared for Soil Handling Sub-committee of the Alberta Pipeline Environmental Steering Committee. June 1996. Available at: https://extranet.gov.ab.ca/env/infocentre/info/library/6861.pdf. Accessed July 2016.

[42] CAPP (Canadian Association of Petroleum Producers), CEPA (Canadian Energy Pipeline Association) and CGA (Canadian Gas Association). 2012. Pipeline Associated Watercourse Crossings, Fourth Edition. Prepared by TERA Environmental Consultants. Calgary, Alberta. Available at: http://www.cepa.com/wp-content/uploads/2014/01/FourthEdition_WatercourseCrossingManual_Nov2012.pdf. Accessed July 2016.

[43] Enbridge 2012a. Construction and Maintenance Manual.

[44] Enbridge 2012b. Environmental Guidelines for Construction.

[45] TCPL (TransCanada Pipelines Ltd). 2011. Engineering Specification TES-PROJ-COM Compaction Control Measures for Pipeline Excavations.

[46] TCPL (TransCanada Pipelines Ltd). 2014. Engineering Specification TES-DV31-2333 Excavation, Backfilling and Grading. Item ID: 000006457.

[47] TCPL (TransCanada Pipelines Ltd). 2015a. Engineering Specification TES-PROJ-SSW Steep Slope Work Specification. EDMS No.: 009199892.

[48] CEPA (Canadian Energy Pipeline Associations). 2014. Pipeline Watercourse Management-Recommended Practices, 1st Ed.

[49] CEPA Foundation and INGAA Foundation, 2016. A Practical Guide for Pipeline Construction Inspectors.

[50] IECA (International Erosion Control Association). 2015. Appendix P: Land-based Pipeline Construction in Best Practice Erosion and Sediment Control. Available at: https://www.austieca.com.au/documents/item/608 . Accessed July 2016.

[51] GGHACA (Greater Golden Horseshoe Area Conservation Authorities). 2006. Erosion and Sediment Control Guidelines for Urban Construction. Available at: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2013/01/ESC-Guideline-December-2006.pdf . Accessed July 2016.

[52] USACE (United States Army Corps of Engineers). 2016. Erosion and Sediment Control Guidelines for Pipeline Projects. Available at: http://www.swl.usace.army.mil/Portals/50/docs/regulatory/Sedimenatation-Erosion%20Control.pdf. Accessed July 2016.

[53] TRCA (Toronto and Region Conservation Authority). 2009. Erosion and Sediment Control Practices Evaluation. Prepared by TRCA under the Sustainable Technologies Program. Available at: http://www.sustainabletechnologies.ca/wp/wp-content/uploads/2013/02/ESC-Practices-Evaluation-Final.pdf. Accessed July 2016.

[54] AEP (Alberta Environment and Parks). 2014a. Innovative Pipeline Strategies. Available at: http://aep.alberta.ca/about-us/partnerships/partners-in-resource-excellence/innovative-pipeline-strategies.aspx. Accessed July 2016.

[55] AEP (Alberta Environment and Parks). 2014b. Evergreen Centre for Resource Excellence and Innovation. Available at: http://aep.alberta.ca/about-us/partnerships/partners-in-resource-excellence/evergreen-centre-for-resource-excellence-and-innovation.aspx. Accessed July 2016.

[56] TRCA. 2014. Polymer Backgrounder: the Nature, Efficacy and Safety of Polymers for Erosion and Sediment Control. Available at: http://sustainabletechnologies.ca/wp/wp-content/uploads/2013/02/Polymer-Backgrounder-Final.pdf. Accessed July 2016.

[57] CEPA (Canadian Energy Pipeline Association). 2016. Adapting to Regulatory Changes for Protection of Wetlands and Transmission Industry Opportunities. Available at: http://www.albertacga.ca/resources/Documents/Events/Albertas-New-Wetland-Policy-Seminar-2016/Canadian%20Energy%20Pipeline%20Assn%20Presentation.pdf. Accessed July 2016.

[58] JRP (the Joint Public Review Panel Report). 1997. Sable Gas Project. Prepared by the Canadian Environmental Assessment Agency and Natural Resources Canada. October, 1997. Available at: http://publications.gc.ca/collections/Collection/NE23-91-1997E.pdf. Accessed July 2016.

[59] Spectra (Spectra Energy). 2010. Environmental Manual for Construction Projects in Canada, Second Edition. May 2010. Available at: https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90464/90550/450547/650696/647058/A1V8G5_-_Environmental_Manual_for_Construction_Projects_in_Canada_2nd_Edition_May_2010.pdf?_gc_lang=en&nodeid=647062&vernum=0. Accessed July 2016.

[60] TCPL (TransCanada Pipelines Ltd). 2015. Energy East Project Blasting Management Plan. Available at: https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90464/90552/2432218/2540913/2543426/2995824/2957429/A76945-4_V7_Appendix_7-4_Blasting_Management_Program_-_A5A3E8.pdf?nodeid=2958097&vernum=-2. Accessed July 2016.

[61] CEPA (Canadian Energy Pipeline Association). 2012. How does the industry protect Canada’s rivers, streams and lakes during a pipeline crossing? Available at: http://www.cepa.com/wp-content/uploads/2012/09/CEPA-Factsheet_WatercourseCrossing_web.pdf. Accessed July 2016.

[62] DFO (Fisheries and Oceans Canada). 2013a. Fisheries Protection Policy Statement. Ecosystem Programs Policy, Fisheries and Oceans Canada, Ottawa, Ontario. Available at: http://www.dfo-mpo.gc.ca/pnw-ppe/pol/PolicyStatement-EnoncePolitique-eng.pdf. Accessed July 2016.

[63] CAPP (Canadian Association of Petroleum Producers), CEPA (Canadian Energy Pipeline Association) and CGA (Canadian Gas Association). 2005. Pipeline Associated Watercourse Crossings, Third Edition. Prepared by TERA Environmental Consultants and Salmo Consulting Inc. Calgary, Alberta. Available at: http://www.cepa.com/wp-content/uploads/2014/01/Pipelines-Associated-Watercourse-Crossings.pdf. Accessed July 2016.

[64] TRCA, 2013. ((Toronto and Region Conservation Authority). Interim Technical Guidelines for the Development of Environmental Management Plans for Underground Infrastructure.

[65] TRCA, 2015a (Toronto and Region Conservation Authority). Crossings Guideline for Valley and Stream Corridors.

[66] TRB (Transportation Research Board). 2006. National Cooperative Highway Research Program Synthesis 363: Control of Invasive Species: A Synthesis of Highway Practice. Prepared by the National Cooperative Highway Research Program. Available at: http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_363.pdf. Accessed July 2016.

[67] CIPC (California Invasive Plant Council). 2012. Preventing the Spread of Invasive Plants: Best Management Practices for Transportation and Utility Corridors. Cal-IPC Publication 2012-01. California Invasive Plant Council, Berkeley, CA. Available at: http://www.cal-ipc.org/ip/prevention/tuc.php. Accessed July 2016.

[68] OIPC (Ontario Invasive Plant Council). 2013. The Clean Equipment Protocol for Industry. Available at: http://www.ontarioinvasiveplants.ca/files/CleanEquipmentProtocol_Mar152013_D3_FINAL.pdf. Accessed July 2016

[69] ISCBC (Invasive Species Council of British Columbia). 2014. Zebra and Quagga Mussels. Available at: http://bcinvasives.ca/invasive-species/identify/invasive-species/invasive-animals/zebra-and-quagga-mussels/. Accessed July 2016.

[70] Pejchar, Liba and Mooney, Harold A. 2009. Invasive species, ecosystem services and human well-being in Trends in Ecology & Evolution 24, 9 (July 2009): 497-504. Available at: https://www.researchgate.net/publication/26647743_Pejchar_L_and_H_Mooney_Invasive_species_ecosystem_services_and_human_well-being_Trends_in_Ecology_Evolution. Accessed July 2016.

[71] CEAA (Canadian Environmental Assessment Agency). 2012. Considering Aboriginal traditional knowledge in environmental assessments conducted under the Canadian

Environmental Assessment Act -- Interim Principles. https://www.ceaa-acee.gc.ca/default.asp?lang=en&n=4A795E76-1. Accessed July 2016.

[72] Government of Alberta. 2016. The Government of Alberta's Guidelines on Consultation with Metis Settlements on Land and Natural Resource Management. http://www.indigenous.alberta.ca/documents/GOA-Guidelines-Consultation-Metis-LandNaturalResourceManagement-2016.pdf?0.1898236863107831. Accessed July 2016.

[73] NEB (National Energy Board). 2015a. National Energy Board Filing Manual. Available at: https://www.neb-one.gc.ca/bts/ctrg/gnnb/flngmnl/index-eng.html. Accessed July 2016.

[74] Powter, Chris B., John J. Doornbos, and M. Anne Naeth. 2015. Aboriginal Participation in Land Reclamation: Enhancing Dialogue – Report on a Workshop held March 23, 2015. Prepared for Land Reclamation International Graduate School, University of Alberta and the Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta.

[75] JRP (Joint Review Panel for the Enbridge Northern Gateway Project). 2013. Considerations: Report of the Joint Review Panel for the Enbridge Northern Gateway Project Volume 2. The Publication Office, National Energy Board. Calgary Alberta. http://gatewaypanel.review-examen.gc.ca/clf-nsi/dcmnt/rcmndtnsrprt/rcmndtnsrprtvlm2-eng.pdf. Accessed July 2016.

[76] NEB (National Energy Board). 2016. Emergency Management Information. Available at: https://www.neb-one.gc.ca/sftnvrnmnt/mrgnc/rspns/index-eng.html. Accessed July 2016.

[77] Government of Alberta. 2010. Industrial Activity in Foothills Fescue Grasslands. Available at: http://aep.alberta.ca/lands-forests/grazing-range-management/documents/Grassland-MinimizingSurfaceDisturbance.pdf. Accessed July 2016.

[78] CEPA (Canadian Energy Pipeline Association). 2013. How hydrostatic testing helps maintain pipeline integrity. Available at: http://aboutpipelines.com/en/blog/how-hydrostatic-testing-helps-maintain-pipeline-integrity/. Accessed July 2016.

[79] DFO (Fisheries and Oceans Canada). 2013b. Framework for assessing the ecological flow requirements to support fisheries in Canada. Canadian Science Advisory Secretariat, Science Advisory Report 2013/017. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2013/2013_017-eng.pdf. Accessed July 2016.

[80] AENV (Alberta Environment). 2011. Alberta Desk-top Method for Determining Environmental Flows. Water Policy Branch, June 2011. Available at: http://esrd.alberta.ca/water/programs-and-services/water-for-life/healthy-aquatic-ecosystems/documents/DesktopMethodEnvironmentalFlows-Jun2011.pdf. Accessed July 2016.

[81] Alberta Environment. 2016. Hydrostatic Testing of Pipelines: Facts at your fingertips. Available at: http://esrd.alberta.ca/water/education-guidelines/documents/HydrostaticTestingPipelines-FactSheet.pdf. Accessed July 2016.

82 Government of Alberta. 1999. Code of Practice for the Release of Hydrostatic Test Water from Hydrostatic Testing of Petroleum Liquid and Gas Pipelines. Available at: http://www.qp.alberta.ca/documents/codes/RELEASE.PDF. Accessed July 2016.

83 Government of Saskatchewan. 2014. Hydrostatic Testing, Saskatchewan Environmental Code Edition 1. Chapter C.3.1. Adopted Pursuant to the Environmental Management and Protection Act, 2010. Available at: http://environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=95348c74-0798-4b37-8a55-2f2ada35c394. Accessed July 2016.

84 Alberta Environment. 2001. Guide to the Code of Practice for the Temporary Diversion of water for hydrostatic testing of pipelines (water act) and the Code of Practice for the Release of Hydrostatic Test Water from Hydrostatic Testing of Petroleum Liquid and Gas Pipelines (Environmental Enhancement Act). Available at: http://aep.alberta.ca/water/legislation-guidelines/documents/HydrostaticTestingGuide-Mar2001.pdf. Accessed July 2016.

85 BC OGC (British Columbia Oil and Gas Commission). 2009. British Columbia Noise Control Best Practices Guidelines. Available at: https://www.bcogc.ca/british-columbia-noise-control-best-practices-guideline-0. Accessed July 2016.

86 AER (Alberta Energy Regulator). 2007. Directive 038: Noise Control. Available at: https://www.aer.ca/rules-and-regulations/directives/directive-038. Accessed July 2016.

87 IFC (International Finance Corporation). 2007b. Environmental Health and Safety Guidelines (EHS) General EHS Guidelines: Environmental – Noise Management. IFC World Bank Group. Available at: http://www.ifc.org/wps/wcm/connect/06e3b50048865838b4c6f66a6515bb18/1-7%2BNoise.pdf?MOD=AJPERES. Accessed July 2016.

88 National Grid. 2015. Review of Best Available Techniques for Mitigation of Pipework Noise. Nia Final Report. Available at: http://www.smarternetworks.org/NIA_PEA_Docs/NIA_NGGT0053_Pipeline_Noise_Mitigation_-Final_Repo_150714111738.pdf. Accessed July 2016

89 Mulhall, Louise. 2015. Engery Global Oilfield Technology: Latest Capabilities of Satellite Imaging. Available at: http://www.energyglobal.com/upstream/special-reports/28082015/Latest-capabilities-of-satellite-imaging/. Accessed July 2016.

90 US EPA (United States Environmental Protection Agency). 2015. Control Techniques Guidelines for the Oil and Gas Industry (Draft). EPA-453/P-15-001. Office of Air and Radiation, Office of Air Quality Planning and Standards, Sector Policies and Programs Division, Research Triangle Park, North Carolina. Available at: https://www3.epa.gov/airquality/oilandgas/pdfs/og_ctg_draft_081815.pdf. Accessed July 2016

[91] Malm, Howard. 2015. REM Technology Inc: A Comparison of Emissions Reduction Technologies. Available at: http://www.spartancontrols.com/~/media/resources/rem%20technology%20inc/papers/rem%20emission%20reduction%20technology%20comparison%20june2015.pdf?la=en. Accessed July 2016.

[92] OME (Ontario Ministry of the Environment). 2011. Guide for Completing Phase One Environmental Site Assessments under Ontario Regulation 153/04. Available at: https://dr6j45jk9xcmk.cloudfront.net/documents/996/3-6-1-phase-one-environmental-site-assessments-en.pdf. https://dr6j45jk9xcmk.cloudfront.net/documents/996/3-6-1-phase-one-environmental-site-assessments-en.pdf. Accessed July 2016.

[93] Vroblesky, D.A., 2008, User's guide to the collection and analysis of tree cores to assess the distribution of subsurface volatile organic compounds: U.S. Geological Survey Scientific Investigations Report 2008–5088, 59 p. Available at http://pubs.water.usgs.gov/sir2008-5088. Accessed July 2016.

[94] Golder Associates. 2013. Final Report. Region of Waterloo. Sustainable Approaches to Soil, Sediment and Materials Management - Feasibility Study. Available at: http://www.regionofwaterloo.ca/en/aboutTheEnvironment/resources/Soil_Management_Feasibility_Study_Report.pdf. Accessed July 2016.

[95] Lee, Kenneth (chair), Michel Boufadel, Bing Chen, Julia Foght, Peter Hodson, Stella Swanson, Albert Venosa. 2015. Expert Panel Report on the Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments. Royal Society of Canada, Ottawa, ON. ISBN: 978-1- 928140-02-3

[96] RSC (Royal Society of Canada). 2015. The Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments. Available at: http://www.rsc.ca/en/expert-panels/rsc-reports/behaviour-and-environmental-impacts-crude-oil-released-into-aqueous. Accessed July 2016.

[97] NEB (National Energy Board). 2015b. Pipeline Regulation in Canada: A Guide for Landowners and the Public, Chapter 12: Abandonment of a Pipeline. Available at: https://www.neb-one.gc.ca/prtcptn/lndwnrgd/lndwnrgdch12-eng.html. Accessed July 2016.

[98] PASC (Pipeline Abandonment Steering Committee). 1996. Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues. Prepared for PASC by: Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association, Alberta Energy Utilities Board and the National Energy Board.

[99] CEPA (Canadian Energy Pipeline Associations). 2007. Pipeline Abandonment Assumptions: Technical and environmental considerations for development of pipeline abandonment strategies. Prepared for the Terminal Negative Salvage Task Force of the Canadian Energy Pipeline Association.

[100] DNV (Det Norske Veritas). 2010. Pipeline Abandonment Scoping Study. Prepared for the National Energy Board, Report No. EP028844.

[101] CSA (Canadian Standards Association). 2015. Z662-15: Oil and Gas Pipeline Systems. Available at: http://shop.csa.ca/en/canada/petroleum-and-natural-gas-industry-systems/z662-15-/invt/27024912015. Accessed July 2016.

[102] NEB (National Energy Board). 2011. Remediation Process Guide. Available at: https://www.neb-one.gc.ca/sftnvrnmnt/nvrnmnt/rmdtnprcssgd/rmdtnprcssgd-eng.pdf. Accessed July 2016.

[103] DNV (Det Norske Veritas). 2015. Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines. Prepared for the Petroleum Technology Alliance of Canada, Calgary, Alberta, Report No. TAOUS813COSC (PP079627, Rev1).

[104] AITF (Alberta Innovates Technology Futures). 2015. Cleaning of Pipelines for Abandonment. Prepared for Petroleum Technology Alliance of Canada (PTAC). Available at: http://www.ptac.org/projects/400. Accessed July 2016.

[105] NOVA Chemicals. 2015. Fate and Decomposition of Pipe Coating Materials in Abandoned Pipelines. Prepared for Petroleum Technology Alliance Canada (PTAC). Available at: http://www.ptac.org/projects/402. Accessed July 2016.

[106] Stantec (Stantec Consulting Ltd.). 2014. A Study of Frost Heave-related Exposure Risk to Abandoned Transmission Pipelines in Cropland Areas of Southern Canada Stage 1 (Literature Search and Numerical Modeling) Volume 1 (Technical Report). Prepared for the Petroleum Technology Alliance of Canada, Calgary, Alberta.