



**DNV·GL**

# **Review Of Recent Pipeline Abandonment Research**

**PTAC Petroleum Technology Alliance Canada**

**Report No.:** 10126997-1, Rev. 1

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Objective: To review the 2010 "Pipeline Abandonment Scoping Study" conducted by DNV and determine if the recommendations for potential future research projects identified in the 2010 study have been addressed by the Pipeline Abandonment Research Steering Committee's work to date.

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## EXECUTIVE SUMMARY

On 30 August 2018, the Pipeline Abandonment Research Steering Committee (PARSC) issued a Request for Proposals (RFP) titled “PARSC 018 – Review of Recent PARSC Pipeline Abandonment Research”. The objective of the RFP was to review the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV and determine if the recommendations for potential future research projects identified in the 2010 study have been addressed by PARSC’s work to date and if not, what scope elements of the 2010 study remain to be addressed and why. On 31 October 2018 DET NORSKE VERITAS (CANADA) LTD. (Hereinafter Called “DNV GL”) was awarded the contract to conduct “PARSC 018 – Review of Recent PARSC Pipeline Abandonment Research”.

The current review was limited to determining whether each of the specific 2010 recommendations have been addressed by work conducted under PARSC contracts. No additional literature reviews or development of new/amended recommendations was conducted.

It should be noted that only successful proposals, not final reports, were available for work related to items “3.6 Cleaning Methods and Disposal of Cleaning Fluids” and “3.12 Evaluate Success of Previous Pipeline Abandonment Programs”. It was assumed that the final reports for these areas will address the issues outlined in the proposals.

Generally, the work completed under the PARSC contracts has addressed or partially addressed the recommendations included in the 2010 Pipeline Abandonment Scoping Study. For the most part, the additional work required to fully address the recommendations would require longer term field testing and coordination of field testing and predictive models.

Details of the DNV GL review including the identification of gaps in meeting key requirements of the original Scoping Study and reasons why the gaps exist, are included in Section 3 of this report.

Table 1 below summarizes the results of the review of the PARSC projects.

**Table 1: Summary**

DNV Scoping Study Recommendation		Status	Comments
1	Detection of Residual Contamination	Not Addressed	The report does not address the recommendation to develop practical testing protocols. However, it provides recommendations for potential future projects, including pilot scale experiments and field testing which could address the DNV Scoping Study recommendations.
2	Initiate a study to identify compounds to be tested for in soil and water as a result of a pipeline leak at the abandonment phase.	No RFPs issued	
3	Risk Assessment	Partially Addressed	The framework addresses most of the DNV Scoping Study recommendations. However, it is only applicable to abandonment in-place. The framework should be expanded to address abandonment through removal. The framework does not outline potential safeguards to reduce the frequency and/or consequences of a particular event and should be expanded to include a listing of potential safeguards to address all recommendations of the DNV Scoping Study.
4	Conduit Effect	Addressed	
5	Decomposition of Pipe material	Partially Addressed	The study recommends the development of a sampling protocol and subsequent field sampling. This work is expected to address one or more of the outstanding recommendations of the DNV Scoping Study.

<b>6</b>	Cleaning methods and disposal of cleaning fluids	Partially Addressed	The report and proposal do not collectively address all of the recommendations of the DNV Scoping Study. Once the final report is available, the conclusions of this section should be re-evaluated to determine if outstanding recommendations have been addressed.
<b>7</b>	Disposal of pipe material	No RFPs issued	In the absence of standards to determine acceptable concentrations of residual contaminants, there are no recommendations for studies relating to disposal of pipe material to pursue at this time.
<b>8</b>	Abandonment under water bodies	Not Addressed	The report does not address any of the DNV Scoping Study recommendations. However, the Matrix Solutions Inc. report recommends a future workshop, which could address some of the outstanding DNV Scoping Study recommendations. Field tests would be required to fully address the DNV Scoping Study recommendations.
<b>9</b>	Compile Exposure Data from NEB and ERCB Records	Partially Addressed	Due to limitations in available data on pipeline exposure, the report could not fully address the scope of the recommendation set out by the DNV Scoping Study. However, it should meet the expected result, which is to guide the committee to understand the sites most at risk due to exposure, and where exposure is unlikely.
<b>10</b>	Examine Buoyancy Effects on Pipeline Exposure Rates	Addressed	
<b>11</b>	Examine Frost Heave Effects on Pipeline Exposure Rates	Partially Addressed	The recommendation to complete a laboratory study to understand the interaction of growing ice under an abandoned pipeline in relation to resisting forces was

			not undertaken, nor was full-scale field testing. As such, no comparison of laboratory testing results to field measurements were undertaken.
<b>12</b>	Evaluate Success of Previous Pipeline Abandonment Programs	Addressed	Collectively, the report and proposals (once completed) relating to this recommendation are expected to address the scope and expected results of the DNV Scoping Study.
<b>13</b>	Collapse of soil under different void sizes, soil types and depth of cover	Partially Addressed	The recommendation to conduct field-based testing, and the initiation of laboratory-based scale testing to validate the results of the DNV methodology to predict the potential collapse of soil once a pipeline is pulled out or fails due to corrosion were not initiated.
<b>14</b>	Validation of Culvert Failure Model for Abandoned Pipelines	Addressed	
<b>15</b>	Structural Integrity	Addressed	





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# 1 BACKGROUND

## 1.1 Past Studies

Pipeline abandonment has been a topic of discussion in the Canadian oil and gas industry for over 30 years. This summary is taken from the NEB's Land Matters Consultation Initiative, Stream 4 – Pipeline Abandonment - Physical Issues, and is based on three previous studies undertaken in 1985, 1996, and 1997.

In 1985, NEB staff reviewed technical, environmental, and financial issues associated with pipeline abandonment (the 1985 NEB Staff Paper). In 1996, the Pipeline Abandonment Steering Committee, a collaboration of the NEB, Alberta Energy Utilities Board (EUB), Canadian Energy Pipeline Association (CEPA) and Canadian Association of Petroleum Producers (CAPP), developed a discussion paper (the 1996 Discussion Paper) that examined the physical and technical issues associated with abandonment. In particular, this latter paper provides a template for abandonment planning and implementation. In 1997, the same collaboration examined legal issues relating to abandonment (the 1997 Legal Paper).


In addition, as part of the process of developing the 1996 Discussion Paper, the Pipeline Abandonment Steering Committee commissioned four reviews of specific technical issues. The reviews examine trace pipeline contaminants, corrosion, pipeline related subsidence and environmental issues respectively and are also referenced therein.

Physical and technical issues of retirement and reclamation can be organized into six principal sections:

1. Retirement options;
2. Engineering issues;
3. Land use considerations;
4. Environmental issues;
5. Post-abandonment; and
6. Principles for pipeline abandonment.

In 2010 Det Norske Veritas (DNV) together with TERA ENVIRONMENTAL CONSULTANTS and BGC ENGINEERING INC. were contracted by the National Energy Board (NEB) to conduct a literature review regarding the current understanding worldwide with respect to the physical/technical issues associated with onshore pipeline abandonment and use the results of the literature review to critically analyze and identify gaps in current knowledge, and make recommendations as to potential future research projects that could help to fill those gaps.

The project team conducted the literature review based on more than 100 key words applicable to pipeline abandonment. Various combinations of these key words were used to search for published information dealing with issues associated with pipeline abandonment. More than 430 abstracts of published papers were reviewed, and these were narrowed down to 83 relevant documents, which were obtained for more detailed reviews by the subject matter experts (SMEs). In addition, various standards



from North America, South America, Australia, Europe, and the United Kingdom were reviewed for requirements specific to pipeline abandonment.

The final report of the project was issued in November 2010 and included an outline of the existing level of knowledge regarding issues related to pipeline abandonment; identified knowledge gaps and, outlined additional research topics that could be completed in order to address the knowledge gaps. Topics recommended for additional study included:

1. Detection of Residual Contamination
2. Risk Assessment
3. Decomposition of Pipe Materials
4. Cleaning Methods and Disposal of Cleaning Fluids
5. Abandonment under Water Bodies
6. Pipeline Exposure Data from Existing Records
7. Buoyancy Effects on Pipeline Exposure
8. Standard Pipeline Products List
9. Frost Heave Effects on Pipeline Exposure
10. Evaluation of Previous Pipeline Abandonment programs
11. Collapse of Soil Under Various Conditions
12. Validation of Culvert Failure Model for Abandoned Pipelines
13. Validation of Structural Integrity Models


## 1.2 Current Project

On 30 August 2018, the Pipeline Abandonment Research Steering Committee (PARSC) issued a Request for Proposals (RFP) titled “PARSC 018 – Review of Recent PARSC Pipeline Abandonment Research”. The objective of the RFP was to review the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV and determine if the recommendations for potential future research projects identified in the 2010 study have been addressed by PARSC’s work to date and if not, what scope elements of the 2010 study remain to be addressed and why.

On 31 October 2018 DET NORSKE VERITAS (CANADA) LTD. (Hereinafter Called “DNV GL”) was awarded the contract to conduct “PARSC 018 – Review of Recent PARSC Pipeline Abandonment Research”.

## 2 APPROACH

DNV GL project team members were assigned project reports based on their areas of knowledge and they reviewed the projects completed and planned by PARSC and compared those projects against the recommendations outlined in the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV.



This report outlines the results of the review of the PARSC projects, identifies gaps in meeting key requirements of the original Scoping Study and provides reasons why DNV GL feels the gaps exist.

It is noted that the scope of this project did not include conducting an updated literature review on the status of pipeline abandonment research, evaluating the technical accuracy of the research conducted, identifying new knowledge gaps or prioritizing any recommended future work.

## 3 RESULTS

This section presents each of the original recommendations, including the scope and expected results, from the 2010 "Pipeline Abandonment Scoping Study"; identifies which PARSC report addresses the recommendation; and, summarizes whether the original recommendation has been adequately addressed, partially addressed or not addressed. The results are also summarized in the spreadsheet at the end of this section.

It should be noted that final reports were not available for all PARSC projects. In these cases, the Request for Proposal (RFP) issued by PARSC and the successful Proposal accepted by PARSC were reviewed to determine if the project, as proposed would address the scope and expected results of the 2010 Scoping Study.

### 3.1 Detection of Residual Contamination

#### **2010 Recommendation:**

Develop practical testing protocols to accurately quantify residual contaminants remaining inside a section of buried pipe following standard cleaning procedures. The purpose of developing standard sampling protocols is twofold: for one, the chosen methodology would serve to provide an accurate representation of the nature, extent and distribution of contaminants along the pipeline; secondly, such a universal approach would provide user-friendly guidelines for companies and ensure consistent sampling results. Such standard protocols would be developed to determine the initial likelihood of Polychlorinated Biphenyl (PCB) and Naturally occurring radioactive material (NORM) contamination in the pipeline. In doing so, NORMs and/or PCBs would either be included or excluded from further testing.

#### **Scope:**

Standard testing protocols should be developed in consideration of standard practices for detection of hydrocarbons, PCBs and NORMs in pipelines. In order to integrate these contaminants into a standard testing protocol, three separate studies should be conducted:

- Methods to accurately quantify residual hydrocarbons along an abandoned pipeline.
- Develop standard practices for detection of PCBs where suspected in abandoned pipelines.
- Standard practices for detection of NORM-contaminated pipe. (This study could be limited to the pipelines regulated by the NEB. Past experience suggests that NORM contamination in oilfield pipe, fittings and tanks is more likely to be found in upstream oil and gas activities than in the transmission and distribution systems regulated by the NEB).

#### **Expected Results:**

In recommending further research into the environmental effects of pipeline abandonment, the development of a standard testing protocol takes precedence. Many decisions regarding the management and handling of abandoned pipeline hinge on the efficacy and accuracy of contaminant testing. For example, establishing a standard testing protocol may lead to:

- An accurate indication of the potential concentrations of contaminants to be transported down a section of abandoned pipeline as a result of the conduit effect;

- A greater understanding of the nature, extent and distribution of contaminants, which is the first step in developing formal risk assessment tools modelling the fate and effects of detected contaminants in an abandoned pipeline;
- Consistent results, allowing statistical studies of such results to be compiled from various abandonment projects and, over time, lead to the development of a contaminant database with the establishment of categories of expected residual contaminants based on the pipeline product and locations along the pipeline system;
- Greater support for providing an indication of effective cleaning methods; and
- Guidance for decision making on locations for pipeline abandonment in-place.

### **PARSC Projects to Address Recommendations**

1 - Request for Proposals - PARSC 005 - Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines (July 16, 2014)

2 - Alberta Innovates - Technology Futures Report for PARSC 004 and 005- Cleaning of Pipelines for Abandonment (September 2015)


### **Analysis**

PARSC issued a Request for Proposal for PARSC 005 – Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines dated July 16, 2014. The requested project would consist of 2 modules, the first module was to identify compounds to be tested in soil and water in the eventuality of a leak at the abandonment phase, and the second module was to address the topic of Detection of Residual Contamination. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference, set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed. The RFP did not specifically indicate that the detection of PCBs or NORMs would need to be addressed by the project.

The Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment (September 2015) sets out to address the requirements of PTAC PARSC 004 – Cleaning Methods for Abandoned Pipelines and PARSC 005 – Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines.

The main objectives of this study are to:

1. Review pipeline cleaning methods and current technologies for both chemical and mechanical methods;
2. Review pipeline products and identify the list of potential contaminants associated with each commodity;
3. Gather all relevant regulatory information available in Canada (federal and provincial) that address the subject of pipeline abandonment. Standards related to this subject are also reviewed (e.g. NACE International and CSA);

- 
4. Investigate current abandonment programs and practices currently adapted in the industry by pipeline operators; and
  5. Determine the appropriate tests to investigate the degree of contaminants that are actually present upon completion of the pipeline abandonment process and provide a market review of currently available field tests.

In addition, the study presents recommendations including development of guidelines for cleaning abandoned pipelines. The recommended guidelines, which can eventually be transitioned into a standard, would be beneficial to the industry and pipeline operators, as well as the regulators and other stakeholders (e.g. land owners), as it would aim to standardize the process of pipeline abandonment.

The project report does not address the scope and expected results of the 2010 "Pipeline Abandonment Scoping Study" as it relates the detection of residual contamination.

#### **Conclusion – Not Addressed**

The RFP - PARSC 005 - Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines partially addresses the recommendations of the 2010 "Pipeline Abandonment Scoping Study", through incorporation by reference.

The Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment (September 2015) does not address the recommendation of the 2010 "Pipeline Abandonment Scoping Study" to develop practical testing protocols. However, it includes recommendations for the following potential future projects which may address the 2010 "Pipeline Abandonment Scoping Study" recommendations.

1. Develop guidelines for pipeline abandonment
2. Set criteria for the allowable levels for residuals in an abandoned pipeline
3. Pipeline cleaning using progressive pigging and bio-degradable chemicals
4. Case study Enbridge's Line 3 decommissioning project
5. Pilot scale experiment for pipeline abandonment
6. Field testing and sampling for contaminants



## 3.2 Initiate A Study to Identify Compounds to Be Tested for In Soil And Water As A Result Of A Pipeline Leak At The Abandonment Phase.

### **2010 Recommendation:**

Conduct a review of products shipped through NEB regulated pipeline systems.

### **Scope:**

The study should include a thorough review of the Material Safety Data Sheets (MSDS) for all products shipped as well as for products that could enter the pipeline as a result of the operation and at abandonment of the pipeline system.

### **Expected Result:**

The development of a standard list of compounds expected to be found as a result of a pipeline leak. The research should determine the extent to which the list can be applied to abandoned pipelines. A detailed review and evaluation of the list is needed to assess the applicability to pipeline abandonment issues.

### **PARSC Projects to Address Recommendations**

No requests for proposal were issued by the PARSC in relation to this recommendation.

### **Analysis**

No analysis of the research was conducted as there were no projects initiated with respect to this recommendation.

### **Conclusion – Not Assessed**

As discussed in the 2010 “Pipeline Abandonment Scoping Study”, it is anticipated that this project would not constitute a significant level of effort, with an estimated duration of one month.



### 3.3 Risk Assessment

#### 2010 Recommendation:

Given the variability of potential causes of pipeline collapse and the consequences that vary with location and other local environmental factors, it is suggested that an event and consequence analysis be used as a tool to identify scenarios and consequences related to pipeline abandonment.

#### Scope:

The objective of this research would be to identify the various scenarios and related consequences of pipeline abandonment events and identify potential consequences of those events.

#### Expected Result:

The research would determine the potential risk exposure for various events and outline potential safeguards to reduce the frequency and/or consequences of a particular event.

#### PARSC Projects to Address Recommendations

- 1 - Request for Proposals - PARSC 008 – Risk-Based Decision Making Framework for Pipeline Abandonment (March 22, 2016)
- 2 – Arcadis - Risk-Based Decision Making Framework for Pipeline Abandonment (Final) - A Guide for Evaluating Risks Associated with Physical and Technical Hazards Related to Abandonment-In-Place (November 2, 2018)
- 3 - Usability Review of a Guide for Evaluating Pipeline Abandonment Risks


#### Analysis

PARSC issued a Request for Proposal for PARSC 008 – Risk-Based Decision Making Framework for Pipeline Abandonment. The requested project would result in a risk assessment framework for pipeline abandonment that identifies the key hazards and mitigation approaches to reduce the probability and impacts of occurrences. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

Arcadis provided a proposal to PARSC for the development of a framework to guide hazard and risk-based decision making by operators during the planning phases of pipeline abandonment and development of Abandonment Plans for submission to the NEB. The project scope of work would consist of the following tasks:

1. Project kickoff with PTAC/PARSC team
2. Vision planning meeting
3. Stakeholder input
4. Framework development

As the ultimate deliverable, Arcadis would prepare the framework and associated technical guidance document.



Arcadis Report subsequently provided the report titled "Risk-Based Decision-Making Framework for Pipeline Abandonment – Final, A Guide for Evaluating Risks Associated with Physical and Technical Hazards Related to Abandonment-In-Place". The report addressed the scope and expected result as set out in the 2010 "Pipeline Abandonment Scoping Study" conducted by DNV.

It should be noted that the risk assessment framework set out in the report applies to pipelines abandoned in-place. It does not address abandonment via pipeline removal. In addition, the report framework sets out the approach for determining potential safeguards (mitigation measures) and does not outline potential safeguards beyond long-term monitoring programs.

The Arcadis Report sets out a framework whereby pipeline operators can evaluate on a site-specific basis, the risks associated with the physical and technical hazards related to abandoning pipelines in-place. Operators can then determine the need for risk management measures to mitigate these risks. Operators would compare the risks and associated risk management measures for abandonment in-place to those associated with pipeline removal to support the selection of either of these options. It should be noted that the Arcadis report does not provide a framework whereby operators can evaluate risks associated with pipeline removal. These risks must be evaluated and compared to those associated with abandonment in-place prior to final selection of either option.


The framework for abandonment in-place identifies various pipeline abandonment events and the physical and technical hazards associated with these events. In addition, the framework includes consequence analysis for human health and safety, ecology and environment, and land use and valued/economic resources. As a final step, the framework involves identifying risk management measures that could be implemented to mitigate or manage the hazards for which they are required. With the exception of long-term monitoring programs, the report does not explicitly list or describe potential safeguards or mitigation measures to reduce risk associated with any particular abandonment events.

The Arcadis report identifies the various scenarios and related consequences of pipeline abandonment events and identifies potential consequences of such events. The report outlines some potential mitigation measures to reduce the risk of a particular event, but there is no extensive listing of such safeguards. Therefore, the Arcadis report addresses the scope of the studies recommended in the 2010 "Pipeline Abandonment Scoping Study" conducted by DNV but does not fully address the expected result which includes potential safeguards to reduce the frequency or consequences of a particular event.

In December 2017, PTAC requested an independent review of the Arcadis DRAFT report dated August 2017, resulting in recommendations on how the report can be used and what improvements would facilitate its use. The report does not set out to address the recommendations of the 2010 "Pipeline Abandonment Scoping Study" conducted by DNV, but provides recommendations on how the Arcadis Report, Risk-Based Decision Making Framework for Pipeline Abandonment may be used. The final Arcadis report dated November 2, 2018 includes the identified improvements.

### **Conclusion – Partially Addressed**

The Request for Proposal for PARSC 008 – Risk-Based Decision Making Framework for Pipeline Abandonment, through the project objective and scope, and by incorporation by reference of the 2010 "Pipeline Abandonment Scoping Study" set out expectations that the scope and expected results of the 2010 "Pipeline Abandonment Scoping Study" would be addressed.



The Arcadis report titled "Risk-Based Decision-Making Framework for Pipeline Abandonment – Final, A Guide for Evaluating Risks Associated with Physical and Technical Hazards Related to Abandonment-In-Place" addresses the scope of the studies recommended in the 2010 "Pipeline Abandonment Scoping Study" conducted by DNV but does not fully address the expected result which includes potential safeguards to reduce the frequency or consequences of a particular event.

The framework is only applicable to abandonment in-place and does not outline potential safeguards to reduce the frequency and/or consequences of a particular event. The framework itself does not set out recommendations for potential future work. However, the framework could be expanded to include scenarios involving pipeline abandonment through removal and include a listing of potential safeguards that could be applied to mitigate risk.

## 3.4 Conduit Effect

### 2010 Recommendation:

No additional studies were recommended with respect to the potential conduit effect as part of the “Pipeline Abandonment Scoping Study, although it was noted that this issue could be monitored as part of the study recommended in Section 3.12 related to the evaluation of the success of previous pipeline abandonment programs.

### PARSC Projects to Address Recommendations

- 1 - Request for Proposals - PARSC 012 –Water Conduit Effect in Abandoned Pipelines, March 21, 2016
- 2 - AMEC - Water Conduit Effect in Abandoned Pipelines, Pipeline Abandonment Research Steering Committee PARSC 012 (August 2017)

### Analysis

AMEC conducted a detailed literature search and evaluated 4 separate conduit scenarios for abandoned pipe. The four scenarios assessed were contaminated sites, inclines, recharging water bodies (lakes and rivers), and small water bodies (wetlands, sloughs). At the time of the study there were no documented instances of the conduit effect in abandoned pipelines. For each scenario, four separate sources of contamination were considered, namely future contaminant releases, managed historical contamination, unmanaged historical contamination, and external historical contamination. Mitigative options were discussed related to the scenarios and sources consistent with the recommendations contained in the 1996 NEB Pipeline Abandonment Discussion Paper related to plugging of abandoned pipelines, in addition to segmentation and removal.

### Conclusion – Addressed

As it was the opinion of the “Pipeline Abandonment Scoping Study” that this issue was sufficiently understood and researched, the study of the conduit effect in abandoned pipelines is considered addressed. The additional research undertaken by AMEC Foster Wheeler further reinforced the conclusions of the “Pipeline Abandonment Scoping Study” and the 1996 NEB Pipeline Abandonment Discussion Paper.

## 3.5 Decomposition of Pipe Material

### 2010 Recommendation:

The mechanism, rates and effects of pipe corrosion warrants engineering study while considering contamination of soil or groundwater by pipe coatings and their degradation products is worthy of consideration. While not likely to be widespread or dramatic, it should not be ignored. A study of the leaching potentials of pipe coatings (especially older materials such as coal tar coatings) is warranted. Consideration should be given to the environmental and human health effects of the chemicals, the rate and nature of chemical decomposition, potential for soil and groundwater transport and recommendations leading toward improved abandonment/disposal practices.

### Scope:

Study leaching potential and associated human health and environmental effects of the contaminants released from coal tar coatings. A theoretical understanding of the potential for leached contaminants to move through various soil and groundwater regimes, as well as the human and environmental consequences of such contamination, should be established. Concurrently, laboratory testing of the structural integrity and the rate and nature of chemical decomposition of coal tar coatings under simulated field conditions should be undertaken.

### Expected Results:

A greater understanding of the nature and rate of coal tar wrap decomposition, dispersal of leached chemicals in the surrounding environment and the potential human and environmental effects of leached contaminants will contribute to the development of formal risk assessment models with respect to identifying the fate and effects of detected contaminants in an abandoned pipeline with coal tar coating; and the establishment of safe handling and disposal procedures / recycling options for pipelines coated with coal tar wrap.

An understanding of soil and groundwater mechanisms suggests that solution and transport of metal ions in the environment resulting from corroding pipe is worthy of thought but is almost certainly not likely to be a widespread issue. The SMEs suggest this is a topic that can be deferred for future consideration.


### PARSC Projects to Address Recommendations

1 - Request for Proposals - PARSC 006 - Decomposition of Pipe Coating Materials in Abandoned Pipelines, July 16, 2014

2 - Nova Chemicals - Fate and Decomposition of Pipe Coating Materials in Abandoned Pipelines (July 3, 2015)

### Analysis

PARSC issued a Request for Proposal for PARSC 006 – Decomposition of Pipe Coating Materials in Abandoned Pipelines dated July 16, 2014. The requested project would involve a study of the potential contamination of soil or groundwater by pipe coatings and their degradation products. In addition, the RFP indicated that consideration should be given to the environmental and human health effects of the chemicals, the rate and nature of chemical decomposition, potential for soil and groundwater transport



and recommendations leading toward improved abandonment/disposal practices. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.


As set out in its report titled “Fate and Decomposition of Pipe Coating Materials in Abandoned Pipelines”, Nova Chemicals undertook the requested project with the objective of acquiring scientific information about the decomposition products of pipeline coating materials to enable the soil and groundwater contamination risks associated with abandonment to be understood and managed.

In its study, Nova Chemicals reviewed the history and composition of pipeline coating materials. The fate of buried pipeline coatings was assessed with respect to in-situ abandonment. Leachates from the pipeline coatings and their degradation and fate were considered. Based on information from leaching studies in the literature, it was determined that leaching from the coatings has been occurring since the pipeline was originally buried. Consequently, the lower molecular weight, water soluble, easily leachable components have probably all been removed some time ago. Leaching from coal tar and asphalt coatings occurs at a slower rate. These coating materials may have retained the higher molecular weight polyaromatic hydrocarbons (PAHs) which can continue to be leachable post-abandonment. It is recognized that the PAH molecules are toxic and that coating materials containing these molecules would pose more concern for abandoned pipelines. If leaching of PAHs occurs these molecules have low solubility in water and high affinity for organic carbon. This means that if leached, they will be absorbed to soil carbon and will not migrate with soil water or to groundwater. Furthermore, these molecules can be biodegraded by soil microorganisms. Consequently, their contribution to health and environmental risk of abandoned pipelines will be low and will be no greater than risks posed by pipelines containing these materials currently in operation.

The report included the following recommendations:

1. The amount of leachable material still left in pipeline coatings at abandonment should be confirmed by sampling and analysis. A protocol should be developed for sampling in terms of pipeline coating material and the soil environment of the buried pipeline. Ideally soil sampling location should be within 30 cm below the pipe at the 6 o'clock position of the pipeline. Extraction of the soil and analysis of the extract could be based on EPA methods.
2. It has been reported that PCBs were included in coatings manufactured in the period 1940s – 1970s. Asphalt and coal tar coatings from pipelines built in that era should be analysed for the presence of PCBs when plans are made to abandon those pipelines.
3. Samples obtained from pipeline digs should be catalogued as to composition and age. These samples should be analysed for residual composition and subjected to leachate tests to determine rates of release of residual components. A database of such information would be an asset in responding to criticisms of in-situ pipeline abandonment.

The Nova Chemicals study was based on a literature review and addressed the following aspects of the scope and expected results set out in the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV:

- 
- study the leaching potential and associated effects of contaminants released from coal tar coatings;
  - establish a theoretical understanding of the potential for leached contaminants to move through various soil and groundwater regimes, and the human and environmental consequences of such contamination; and
  - provide a greater understanding of the nature and rate of coal tar wrap decomposition, dispersal of leached chemicals in the surrounding environment and the potential human and environmental effects of leached contaminants.

The study did not undertake laboratory testing of the structural integrity and the rate and nature of chemical decomposition of coal tar coatings under simulated field conditions. The study explores the fate and effects of contaminants but does not appear to directly contribute to the development of formal risk assessment models with respect to identifying the fate and effects of detected contaminants in an abandoned pipeline with coal tar coating. In addition, the study does not result in the establishment of safe handling and disposal procedures, or recycling options for pipelines coated with coal tar wrap.

#### **Conclusion – Partially Addressed**

The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

The Nova Chemicals study addressed several aspects of the scope and expected results set out in the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV. However, the study did not undertake laboratory testing of the structural integrity and the rate and nature of chemical decomposition of coal tar coatings under simulated field conditions. The study explores the fate and effects of contaminants but does not appear to directly contribute to the development of formal risk assessment models with respect to identifying the fate and effects of detected contaminants in an abandoned pipeline with coal tar coating. In addition, the study does not result in the establishment of safe handling and disposal procedures, or recycling options for pipelines coated with coal tar wrap.

The Nova Chemicals Study recommends the development of a sampling protocol, and subsequent field sampling. This work is expected to address some recommendations of the 2010 “Pipeline Abandonment Scoping Study”.

## 3.6 Cleaning Methods and Disposal of Cleaning Fluids

### 2010 Recommendation:

To the best of our knowledge, no published reports or field trials of pipe cleaning are available. Although such a study is recommended, it is suggested it be led by qualified engineers and pipeline operators.

### Scope:

An engineer led study should be undertaken to determine effective cleaning methods in an attempt to determine cleanliness parameters for either abandoning pipeline in place or removing sections for reuse or disposal.

### Expected Results:

The development of cleanliness standards following determination of effective cleaning procedures and establishment of an accurate and acceptable sampling protocol are expected to assist in:

- Establishing safe handling and disposal methods for pipelines;
- Providing an indication of the effectiveness of cleaning operations along a given length of pipeline;
- Removing the obscurity in determining "how clean is clean" and streamline the abandonment process in a safe and responsible manner;
- Determining the environmental suitability of the cleaning compounds;
- Handling and disposal of wax, waste petroleum products, spent cleaning compounds, etc.;
- The environmental safety of all practices (risk of spills, emergence preparedness, worker and public health, etc.); and
- Developing achievable cleanliness standards for pipe to be abandoned in place or removed for reuse or disposal.

### PARSC Projects to Address Recommendations


1. Request for Proposals PARSC 004 – Cleaning Methods for Abandoned Pipelines, July 16, 2014
2. Request for Proposals PARSC 007 - Recommended Practice for Cleaning Pipelines for Abandonment – Stage 1, March 22, 2016
3. Alberta Innovates - Technology Futures Report for PARSC 004 and 005- Cleaning of Pipelines for Abandonment (September 2015)
4. DNV GL Proposal for PARSC 007 – Recommended Practice for Cleaning Pipelines for Abandonment (April 14, 2016)

### Analysis

#### ***Request for Proposals PARSC 004 – Cleaning Methods for Abandoned Pipelines***

PARSC issued a Request for Proposal for PARSC 004 – Cleaning Methods for Abandoned Pipelines dated July 16, 2014. The requested project would result in a study to determine the effectiveness of existing cleaning methods with respect to the cleanliness parameters required for abandoned pipeline. The RFP





through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

***Request for Proposals PARSC 007 - Recommended Practice for Cleaning Pipelines for Abandonment – Stage 1***

PARSC issued a Request for Proposal for PARSC 007 - Recommended Practice for Cleaning Pipelines for Abandonment dated March 22, 2016. The requested project would result in a draft recommended practice for cleaning pipelines. The RFP through the project objective and scope, addressed some, but not all scope and expected results as recommended in the DNV Scoping Study. Specifically, the RFP did not set out expectations relating to the following scope and expected results:


- safe handling and disposal methods for pipelines
- determine the environmental suitability of the cleaning compounds
- handling and disposal of wax, waste petroleum products, spent cleaning compounds, etc.
- environmental safety of all practices (risk of spills, emergence preparedness, worker and public health, etc.)
- achievable cleanliness standards for pipe to be abandoned in place or removed for reuse or disposal

***Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment***

The Alberta Innovates - Technology Futures (AITF) study sets out to address the requirements of PTAC PARSC 004 – Cleaning Methods for Abandoned Pipeline and PARSC 005 – Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines.

The main objectives of this study are to:

1. Review pipeline cleaning methods and current technologies for both chemical and mechanical methods;
2. Review pipeline products and identify the list of potential contaminants associated with each commodity;
3. Gather all relevant regulatory information available in Canada (federal and provincial) that address the subject of pipeline abandonment. Standards related to this subject are also reviewed (e.g. NACE International and CSA);
4. Investigate current abandonment programs and practices currently adapted in the industry by pipeline operators; and
5. Determine the appropriate tests to investigate the degree of contaminants that are actually present upon completion of the pipeline abandonment process and provide a market review of currently available field tests.



In addition, the study presents recommendations including development of guidelines for cleaning abandoned pipelines. The recommended guidelines, which can eventually be transitioned into a standard, would be beneficial to the industry and pipeline operators, as well as the regulators and other stakeholders (e.g. land owners), as it would aim to standardize the process of pipeline abandonment.

The project did not fully address the scope of the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV recommendation to determine effective cleaning methods and cleanliness parameters for abandoned pipelines. However, the project did address some of the expected results, including:

- providing an indication of the effectiveness of cleaning operations along a given length of pipeline; and
- determining the environmental suitability of the cleaning compounds.

The project did not specifically achieve the following expected results of the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV:


- establishing safe handling and disposal methods for pipelines;
- removing the obscurity in determining “how clean is clean” and streamline the abandonment process in a safe and responsible manner;
- handling and disposal of wax, waste petroleum products, spent cleaning compounds;
- the environmental safety of all practices (risk of spills, emergence preparedness, worker and public health, etc.); and
- developing achievable cleanliness standards for pipe to be abandoned in place or removed for reuse or disposal.

### ***DNV GL Proposal for PARSC 007 – Recommended Practice for Cleaning Pipelines for Abandonment***

In its proposal dated April 14, 2016, DNV GL proposed a project to build on existing pipeline cleaning guidelines and practices to develop a recommended practice for cleaning of pipelines for abandonment. The project would also involve development of recommended acceptance criteria establishing appropriate levels of cleanliness for abandoned pipelines below which residuals remaining in a pipeline would pose no detrimental impact to the environment. DNV GL proposed to complete the project through three main tasks:

1. Technical Literature Search and Comparison of Industry Practices
2. Development of Cleanliness Acceptance Criteria - “How Clean is Clean”
3. Development of Draft Recommended Practice Document

The proposed scope of work includes the preparation of a Draft Recommended Practice for cleaning of pipelines for abandonment. The recommended practice will be based on currently available industry information and will present a review and summary of the current state of industry knowledge specific to cleaning for abandonment, as well as the recommended practice developed. The Draft Recommended Practice will address methodologies of cleaning and recommend criteria to provide industry guidance related to cleaning practice, and acceptable cleanliness levels. The proposed work will also include a



summary of the current state of industry knowledge specific to cleaning for abandonment. This is expected to entail review and comparison of previous cleaning programs, technical literature, and industry reports. The recommended practice will be relevant to transmission lines and associated laterals and gathering lines. The scope includes abandonment and decommissioning of pipelines but does not include deactivation.

The proposed project would address the scope of the 2010 “Pipeline Abandonment Scoping Study” recommendation. That is, to determine effective cleaning methods and cleanliness parameters for abandoned pipelines. The proposal does not specify the applicability of the study to abandoning a pipeline in place or removing sections for reuse or disposal.

The proposed project specifically indicated it would achieve the following expected results of the 2010 “Pipeline Abandonment Scoping Study”:

- providing an indication of the effectiveness of cleaning operations along a given length of pipeline;
- removing the obscurity in determining "how clean is clean" and streamline the abandonment process in a safe and responsible manner;
- determining the environmental suitability of the cleaning compounds; and
- developing achievable cleanliness standards for pipe to be abandoned in place or removed for reuse or disposal.

The proposal did not specifically indicate the project would achieve the following expected results of the 2010 “Pipeline Abandonment Scoping Study” conducted by DNV:


- establishing safe handling and disposal methods for pipelines;
- handling and disposal of wax, waste petroleum products, spent cleaning compounds; and
- the environmental safety of all practices (risk of spills, emergence preparedness, worker and public health, etc.).

### **Conclusion – Partially Addressed**

The Request for Proposal for PARSC 004 – Cleaning Methods for Abandoned Pipelines, through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference sets out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

The Request for Proposal for PARSC 007 - Recommended Practice for Cleaning Pipelines for Abandonment, through the project objective and scope, addressed some, but not all scope and expected results as recommended in the DNV Scoping Study.

The Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment and DNV GL Proposal for PARSC 007 – Recommended Practice for Cleaning Pipelines for Abandonment partially address the scope of the 2010 “Pipeline Abandonment Scoping Study” recommendation to determine effective cleaning methods and cleanliness parameters for abandoned pipelines.



The Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment and DNV GL Proposal for PARSC 007 – Recommended Practice for Cleaning Pipelines for Abandonment collectively do not address the development of safe handling and disposal methods for pipelines, including handling and disposal of wax, waste petroleum products, spent cleaning compounds, nor the environmental safety of all practices. Once the final DNV GL report is available, the conclusions of this section should be re-evaluated to determine if outstanding recommendations have been addressed.



## 3.7 Disposal of Pipe Material

### **2010 Recommendation:**

Until standards have been developed to determine acceptable concentrations of residual contaminants, recommendations for reuse and/or disposal studies cannot be made. Current options for disposal of pipe materials include complying with the requirements of a government approved landfill.

### **PARSC Projects to Address Recommendations**

No PARSC projects have been initiated.

### **Analysis**

None

### **Conclusion**

None

## 3.8 Abandonment Under Water Bodies

### 2010 Recommendation:

It is recommended that an engineered led study to investigate techniques to remove sections of buried pipeline resulting in little to no surface disturbance with respect to abandonment under water bodies as well as sensitive ecological areas.

### Scope:

Engineering field tests to determine the diameter and length of pipelines and the extent to which they can be pulled from the ground should be conducted.

Potential environmental effects associated with pulling pipe from underneath water bodies for consideration include alterations of stream hydrology as a result of subsidence and structural instability of the bed and bank complex. Potential environmental effects associated with pulling pipe from beneath sensitive ecological areas and wetlands for consideration include subsidence and terrain instability, as well as channeling of surface and subsurface water along the trench and associate subsidence and/or erosion.

### Expected Results:

Recognizing the potential environmental effects associated with pulling pipe from under water bodies and sensitive ecological areas could lead to:

- The establishment of mitigation measures in response to such effects; and
- The establishment of best-practices for abandoning a section of pipeline under a water body or sensitive ecological area.

### PARSC Projects to Address Recommendations


1 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, May 30, 2017

2 - Matrix Solutions Inc. Report – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0 (August 2018)

### Analysis

PARSC issued a Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios dated May 30, 2017. The requested project would result in a study including four components all related to developing a greater understanding of the potential for exposure of abandoned pipelines.

1. Analysis of exposure data of TransCanada, Enbridge, Kinder Morgan and possibly other pipeline operators in order to mine the data and identify typical scenarios that have led to exposure.
2. A scoping study to estimate the longevity in an abandonment situation of buoyancy control measures used to manage Canadian onshore pipelines and identify possible mitigation measures.

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3. A scoping study about abandonment under water bodies and sensitive ecological areas such as wetlands. The study would also investigate low impact pipe removal methods.
  4. Scoping of a field study to take measurements of frost heave exposure potential in abandoned pipelines.

The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

In relation to PARSC 013, the Matrix Solutions Inc. report titled “Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios” provides PARSC with initial scoping of several topics within a broader planning level discussion regarding pipeline abandonment and management of long-term risk associated with pipe abandonment in place. The work involved four topics:


1. Interpretation of pipe exposure data to estimate the likelihood of future pipe exposure of abandoned pipelines.
2. Description of expected buoyancy control longevity for various practices, and recommendations of future studies to improve predictions of buoyancy control longevity.
3. Preparation of a recommended work plan to evaluate low impact pipe removal methods for sensitive ecological areas.
4. Preparation of a recommended work plan to measure the potential for pipe exposure due to frost heave.

To address the third topic, the report describes previous industry guidelines, considerations for assessing pipeline removal methods, an assessment of various common pipeline removal methods, examples of pipeline removal projects, and recommended next steps to further evaluate pipe removal methods at sensitive ecological areas. The proposed next steps include a workshop to more fully explore the environmental considerations and potential consequences of removing abandoned pipes for various site conditions.

The 2010 “Pipeline Abandonment Scoping Study” recommended engineering field tests to determine the diameter and length of pipelines and the extent to which they can be pulled from the ground. The Matrix report evaluated pipe removal feasibility for various installation methods based on the experience of the authors and surveyed construction personnel. The report did not involve engineering field tests to determine the diameter and length of pipelines and the extent to which they can be pulled from the ground.

The report did not address the potential environmental effects associated with pulling pipe from under water bodies and sensitive ecological areas, nor did it establish mitigation measures in response to such effects. The report did not establish best-practices for abandoning a section of pipeline under a water body or sensitive ecological area.

The report proposed next steps to further evaluate pipe removal methods at sensitive ecological areas, including a workshop to more fully explore the environmental considerations and potential consequences of removing abandoned pipes for various site conditions.



While the report does not address the 2010 “Pipeline Abandonment Scoping Study” recommendation, nor achieve the expected results, it is anticipated that the proposed next steps would address the recommendations of the 2010 “Pipeline Abandonment Scoping Study”, to some extent.

**Conclusion – Not Addressed**

The Request for Proposal for PARSC 013 – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference sets out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

The Matrix Solutions Inc. report titled “Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios” does not address the 2010 “Pipeline Abandonment Scoping Study” recommendations, nor achieve the expected results. However, it is anticipated that the proposed next steps would address the recommendations of the 2010 “Pipeline Abandonment Scoping Study” to some extent. Field tests would be required to fully address the DNV Scoping Study recommendations.



## 3.9 Compile Exposure Data from NEB and ERCB Records

### 2010 Recommendation:

The objective of the proposed research is to expand the database by compiling an updated list of exposure instances.

### Scope:

Using GIS and NEB/ERCB records, correlate exposures with hydrotechnical, geotechnical and wind erosion hazards (this would include third party damages due to reduced depth of cover) where possible.

### Expected Result:

This can help guide the committee to understand the sites most at risk due to exposure, and where exposure is unlikely.

### PARSC Projects to Address Recommendations

1 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, May 30, 2017

2 - Matrix Solutions Inc. Report – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0 (August 2018)


### Analysis

PARSC issued a Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios dated May 30, 2017. The requested project would result in a study including four components all related to developing a greater understanding of the potential for exposure of abandoned pipelines.

1. Analysis of exposure data of TransCanada, Enbridge, Kinder Morgan and possibly other pipeline operators in order to mine the data and identify typical scenarios that have led to exposure.
2. A scoping study to estimate the longevity in an abandonment situation of buoyancy control measures used to manage Canadian onshore pipelines and identify possible mitigation measures.
3. A scoping study about abandonment under water bodies and sensitive ecological areas such as wetlands. The study would also investigate low impact pipe removal methods.
4. Scoping of a field study to take measurements of frost heave exposure potential in abandoned pipelines.

The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

In connection with the PARSC 013 project, Matrix Solutions Inc. provided a report titled “Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0” to PARSC with initial scoping of several topics within a broader planning level discussion regarding pipeline



abandonment and management of long-term risk associated with pipe abandonment in place. The work involved four topics:

1. Interpretation of pipe exposure data to estimate the likelihood of future pipe exposure of abandoned pipelines.
2. Description of expected buoyancy control longevity for various practices, and recommendations of future studies to improve predictions of buoyancy control longevity.
3. Preparation of a recommended work plan to evaluate low impact pipe removal methods for sensitive ecological areas.
4. Preparation of a recommended work plan to measure the potential for pipe exposure due to frost heave.

The Matrix report indicated that regulatory agencies generally do not report statistics for exposed pipelines, and do not report statistics for exposed pipelines that are abandoned in place. In the absence of direct historical records for abandoned pipelines or for operating pipelines that are exposed, a qualitative estimate of exposed pipeline frequency after abandonment was derived from an interpretation of available literature and published incident data. Most of these “incidents” are expected to occur at water crossings. Mountainous areas and erodible soils are expected to have a relatively higher frequency of exposures. Removal of pipe at selected hazard locations may reduce the frequency of pipe exposures.

The 2010 “Pipeline Abandonment Scoping Study” recommended that research be conducted to expand the database by compiling an updated list of exposure instances. It also recommended using GIS and NEB/ERCB records to correlate exposures with hydrotechnical, geotechnical and wind erosion hazards, including third party damages due to reduced depth of cover, where possible.


Since regulatory agencies generally do not report statistics for exposed pipelines, and by extension, do not report statistics for exposed pipelines that are abandoned in place, an interpretation of available literature to estimate the relative potential for abandoned pipelines to be exposed was provided. The interpretation focused on hydrotechnical and geotechnical hazards and did not specifically address wind erosion hazards. In addition, third party damages due to reduced depth of cover was not addressed.

While the Matrix report did not fully address the scope of the recommendation set out by the 2010 “Pipeline Abandonment Scoping Study”, it should address the expected result. That is, to guide the committee to understand the sites most at risk due to exposure, and where exposure is unlikely. Specifically, the report suggests that hydrotechnical hazards are the most likely hazard of concern for exposure of abandoned pipelines.

### **Conclusion – Partially Addressed**

The Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

Due to limitations in available data on pipeline exposure, the Matrix report could not fully address the scope of the recommendation set out by the 2010 “Pipeline Abandonment Scoping Study”. However, it



should address the expected result. That is, to guide the committee to understand the sites most at risk due to exposure, and where exposure is unlikely.

## 3.10 Examine Buoyancy Effects on Pipeline Exposure Rates

### 2010 Recommendation:

A geohazard that is thought to have the potential to significantly increase the rate of exposure post-abandonment is loss of buoyancy control. The objective of the proposed research is to study the longevity of different buoyancy control measures.

### Scope:

Liquid pipelines depend on the weight of the product to, in part, control buoyancy. Once the pipeline is abandoned, this additional weight will be removed. For gas pipelines, buoyancy control is installed and maintained during the active phase of the pipeline use. Degradation of these control measures is likely to result in exposure if the initial conditions persist. When considering the need for this study, abandonment measures such as removal of the pipeline, installation of interior weight and puncture of the line should be considered as alternatives.

### Expected Result:

The results of the research will be to develop a model that could be used to predict the potential for and the timing of exposure of abandoned pipelines due to lack of or loss of buoyancy control.

### PARSC Projects to Address Recommendations


1 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, May 30, 2017

2 - Matrix Solutions Inc. Report – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0 (August 2018)

### Analysis

PARSC issued a Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios dated May 30, 2017. The requested project would result in a study including four components all related to developing a greater understanding of the potential for exposure of abandoned pipelines.

1. Analysis of exposure data of TransCanada, Enbridge, Kinder Morgan and possibly other pipeline operators in order to mine the data and identify typical scenarios that have led to exposure.
2. A scoping study to estimate the longevity in an abandonment situation of buoyancy control measures used to manage Canadian onshore pipelines and identify possible mitigation measures.
3. A scoping study about abandonment under water bodies and sensitive ecological areas such as wetlands. The study would also investigate low impact pipe removal methods.
4. Scoping of a field study to take measurements of frost heave exposure potential in abandoned pipelines.



The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

In connection with the PARSC 013 project, Matrix Solutions Inc. provided a report titled “Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0” to PARSC. The Matrix report details the various types and applications of buoyancy control used on pipelines and their long-term performance. Four main areas of research related to the PARSC initiative were explored in varying levels of detail, namely interpretation of pipe exposure data relative to the likelihood of exposure of an abandoned pipeline; buoyancy control longevity; low impact pipe removal methods in sensitive ecological areas; and the potential for pipe exposure due to frost heave.


The report indicates:

- After reviewing the various buoyancy control measures that are known to have been used in Canada, it is considered that most of these measures likely will outlive the integrity of the steel wall of the abandoned pipeline, unless the pipeline continues to be cathodically protected.
- The buoyancy control measure that may be most at risk from long-term degradation are steel anchors. Anchor degradation over the long-term will depend significantly on the initial thickness of the various steel components, whether they were coated, local soil corrosivity, groundwater levels and their variation, and groundwater mineral content. The other major buoyancy control measures such as concrete weighting and geotextile bags are expected to last many decades, even after pipe abandonment.
- The long-term integrity of buoyancy control measures must also be considered in conjunction with the long-term integrity of the pipeline wall itself. If through-wall corrosion occurs at only a few locations in a wetland, these points will allow water into the pipe and the pipe’s natural buoyancy will be reduced or negated.
- Finally, the effect of a buoyancy control failure along an abandoned pipeline may also be mitigated by neutralizing the pipeline buoyancy, such as cutting the pipe or drilling holes to perforate the pipe wall. This style of mitigation will need to be considered in conjunction with related hydrotechnical hazards to avoid diverting a watercourse along the abandoned pipeline.

### **Conclusion - Addressed**

The Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

Based on the assessment of the Matrix report specifically related to the buoyancy effects of pipeline exposure rates, the content of the report fully addresses the scope of the recommendation set out by the 2010 “Pipeline Abandonment Scoping Study”. It should be noted that based on the results and conclusions of the Matrix Report, the expected result of a model to be used to predict the potential for,



and the timing of, exposure of abandoned pipelines due to lack of or loss of buoyancy control was not required and was thus not addressed.

## 3.11 Examine Frost Heave Effects on Pipeline Exposure Rates

### 2010 Recommendation:

Frost heave also has the potential to result in pipeline exposure. Once the warm product is removed, heave of the pipeline could begin to occur. The objective of the proposed research is to understand the mechanism of heaving of abandoned pipelines. A laboratory study could be undertaken to examine, under multiple freeze thaw cycles, the interaction of growing ice under the pipeline against resistance forces above the pipeline.

### Scope:

The studies could take three forms; laboratory testing of soils for frost heave properties, field measurement of heave rates in a single winter and across multiple seasons, and examination of the long-term performance of pipelines that are suspended or operating at ambient temperatures.

This type of work has been conceived many times for cold gas pipelines, but only a limited amount of information is in the public domain and testing of the abandonment case was not found in the literature.

The laboratory scale work should be compared to results of field studies of pipelines with product at ambient temperatures or for suspended pipelines. The field scale study would be used to determine the effect of frost on long segments of pipe, versus local frost heave effects that could be determined in the laboratory. The study should include installation of markers on the pipeline and a regular program of surveying the markers. Survey stations should be set-up in a number of different terrains and soil moisture conditions. Thermistors should be installed to monitor the development of the frost front at these stations.

An examination of pipelines operating for a long period at ambient temperatures or where operations have been suspended, should offer a good perspective on the performance of abandoned pipelines.

### Expected Result:

The laboratory results of the research will be to develop a numerical model to determine the effects of different soil types and moisture conditions on the potential for an abandoned pipeline to become jacked out of the ground by frost action. The result of this lab study would not be definitive but give general guidance.

The field study of suspended pipelines or ambient temperature product pipeline would provide real scale information related to local frost heave effects on a long section of pipeline.

### PARSC Projects to Address Recommendations

1 - Project Description - Letter of Interest Request - PARSC 003 - Frost Heave Effects on Pipeline Exposure Rates, July 9, 2013

2 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, May 30, 2017

3 - Matrix Solutions Inc. Report – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0 (August 2018)

4 - Stantec Consulting Ltd. Report - 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 – November 3, 2014)

5 - Stantec Consulting Ltd. Report - 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 2 (Appendices – November 3, 2014)

## **Analysis**

PARSC issued a Letter of Interest (LOI) for PARSC 003 - Frost Heave Effects on Pipeline Exposure Rates dated July 9, 2013. The requested project would result in a study including obtaining a better understanding of the mechanism and ability of frost heave to expose a pipeline and the validation of the concepts on active and/or inactive pipelines.

The LOI through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

PARSC issued a Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios dated May 30, 2017. The requested project would result in a study including four components all related to developing a greater understanding of the potential for exposure of abandoned pipelines.


1. Analysis of exposure data of TransCanada, Enbridge, Kinder Morgan and possibly other pipeline operators in order to mine the data and identify typical scenarios that have led to exposure.
2. A scoping study to estimate the longevity in an abandonment situation of buoyancy control measures used to manage Canadian onshore pipelines and identify possible mitigation measures.
3. A scoping study about abandonment under water bodies and sensitive ecological areas such as wetlands. The study would also investigate low impact pipe removal methods.
4. Scoping of a field study to take measurements of frost heave exposure potential in abandoned pipelines.

The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

In connection with the PARSC 003 project, Stantec Consulting Ltd. provided a report titled “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) and Volume 2 (Appendices)” to PARSC. The Stantec report provides the PARSC committee a thorough assessment of the available literature related to frost action on buried/abandoned pipelines and builds off the original literature review completed by DNV GL as part of the “Pipeline Abandonment Scoping Study”. A series of six targeted reviews of the literature were performed as follows:

- 1- Core Literature Search





i- (Numerical models of frost heaving in soils [Literature Review 1])

## 2- Secondary Literature Searches

i- Frost penetration depth in soils (Literature Review 2)

ii- Pipeline depth (Literature Review 3)

iii- Soil structure and strength of frozen soils (Literature Review 4)

iv- Water and wind erosion within transmission pipeline ROWs (Literature Review 5)

v- Update DNV (2010) report literature review on frost heaving (Literature Review 6)

The report contains a detailed discussion of the geotechnical causes of pipeline exposure including the mechanism of frost heave.

An assessment and analysis of results of the industry accepted numerical modelling methodologies results in two primary "schools of thought," providing two separate approaches to assess the frost heave impacts on pipelines, with both methodologies having pros and cons. The Primary limiting factor to the adoption and use of the models is the age of the research and the software platforms that the numerical models were developed. Modernization of the programming language and the model interface is required to streamline the assessment process. The modelling would utilize a 3-Tiered approach, with Tier 1 providing a pre-screening methodology to identify susceptibility based on climatic conditions. Tier 2 provides a more detailed assessment of geographic or specific ROW conditions, incorporating soil conditions, while Tier 3 provides a comprehensive assessment, utilizing thermodynamic principles to assess the risk of frost heave.


A discussion of the areas of additional research is included, specifically to the Stage 2 and 3 research areas as identified by PARSC.

In connection with the PARSC 013 project, Matrix Solutions Inc. provided a report titled "Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, PARSC 013, Version 2.0" to PARSC. The Matrix report summarizes that the potential for frost heave or frost jacking to expose an abandoned pipeline would be low due to a differing view of the boundary conditions acting on the abandoned pipeline assumed by the Matrix report versus the Stantec report. It would be expected that field trials would effectively answer the susceptibility question and address the alternate views of the two reports. A less detailed assessment of the numerical modelling methodologies is discussed in the Matrix report, with a more detailed discussion of the laboratory and field studies required to assess the impacts of frost heave/jacking contained in the Stantec report.

### **Conclusion – Partially Addressed**

The Letter of Interest Request for PARSC 003 - Frost Heave Effects on Pipeline Exposure Rates and the Request for Proposal for PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, through the project objective and scope, and through incorporation of the 2010 "Pipeline Abandonment Scoping Study" by reference set out expectations that the scope and expected results of the 2010 "Pipeline Abandonment Scoping Study" would be addressed.

The content of the Stantec and Matrix reports both partially address the scope and expected results of the 2010 "Pipeline Abandonment Scoping Study". The scope item related to the understanding of the



mechanisms of heaving of abandoned pipelines was addressed by both reports, while the scope item related to undertaking a laboratory study to understand the interaction of growing ice under an abandoned pipeline in relation to resisting forces was not undertaken by either report, with both reports providing discussion related to the potential testing apparatus to be used and the methodology to conduct the testing, partially addressing the scope area. As such, no comparison of laboratory testing results to field measurements were undertaken by either report, resulting in this scope item not being addressed. It is anticipated that the laboratory testing portion of the 2010 “Pipeline Abandonment Scoping Study” recommendations would constitute an intermediate level of effort and would provide corroboration of the conclusions of the mechanisms of heaving of abandoned pipelines compiled as part of the completed research. The correlation of laboratory results with field data is contingent on the initiation of full-scale field-based studies.

The Stantec report developed a preliminary model to determine the effects of different soil types and moisture conditions on the potential for an abandoned pipeline to become jacked out of the ground by frost action, with additional development and refinement of the model recommended, while neither report undertook field studies to provide real scale information related to local frost heave effects on a long section of pipeline. It is anticipated that the further refinement of the model to predict the potential effects of frost heave of abandoned pipelines would constitute an intermediate level of effort, while the initiation of full-scale field-based studies to study the effects of frost heave would involve significant time, effort and monetary considerations.

## 3.12 Evaluate Success of Previous Pipeline Abandonment Programs

### 2010 Recommendation:

Pipelines have previously been abandoned in Alberta and other jurisdictions. A review of the approved plans could be conducted to gain a general understanding of the approaches taken. Then, if site visits were conducted to determine the effectiveness of activities, valuable information could be obtained on post-abandonment conditions and performance of various abandonment procedures. The objective of the proposed research is to compile “real time” information with respect to actual procedures used for pipeline abandonment.

### Scope:

The scope of the project could cover any abandoned pipelines under NEB or ERCB jurisdiction. A report could be assembled detailing the approaches taken for each site and could include the study of the current ground surface effect of pipelines that are abandoned in place; the study of the current ground surface effects of pipelines that have been removed; and the selection of segments of pipelines that have been abandoned in place, remove them, and observe ground surface changes.

### Expected Result:

The results of the research will provide a better understanding of the effects of actual abandonment procedures.


### PARSC Projects to Address Recommendations

- 1 - Request for Proposals - PARSC 010 – Review of Previous Pipeline Abandonment Programs, September 16, 2016
- 2 - Request for Proposals - PARSC 015 - Review of Previous Pipeline Abandonment Programs, Phase 3 – Abandonment on Farmland, August 28, 2017
- 3 - Request for Proposals - PARSC 016 - Peace River Abandoned Pipeline Segment Field Study [Segment abandoned between 1972 and 1979], July 11, 2018
- 4 - CH2M Final Report - PARSC 010 – Review of Previous Pipeline Abandonment Program – TransCanada Peace River Mainline (February 2018)
- 5 - CH2M Proposal - PARSC 015 – Review of Previous Pipeline Abandonment Programs Phase 3 (October 6, 2017)
6. CH2M Proposal - PARSC 016 – Peace River Abandoned Pipeline Segment Field Study (September 21, 2018)

### Analysis

#### ***Request for Proposals - PARSC 010 – Review of Previous Pipeline Abandonment Programs***

PARSC issued a Request for Proposal for PARSC 010 – Review of Previous Pipeline Abandonment Programs dated September 16, 2016. The requested project will review the present-day state of pipelines that were abandoned more than 10 years ago and to evaluate outcomes achieved by the



abandonment program. The results will provide a better understanding of the actual results of the abandonment procedures that were used. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

***Request for Proposals - PARSC 015 - Review of Previous Pipeline Abandonment Programs, Phase 3 – Abandonment on Farmland***

PARSC issued a Request for Proposal for PARSC 015 - Review of Previous Pipeline Abandonment Programs, Phase 3 – Abandonment on Farmland dated August 28, 2017. The requested project will review the present-day state of pipelines that were abandoned more than 10 years ago and to evaluate outcomes achieved by the abandonment program. The results will provide a better understanding of the actual results of the abandonment procedures that were used. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

***Request for Proposals - PARSC 016 - Peace River Abandoned Pipeline Segment Field Study***

PARSC issued a Request for Proposal for PARSC 016 - Peace River Abandoned Pipeline Segment Field Study [Segment abandoned between 1972 and 1979] dated July 11, 2018. The requested project would implement the recommendations from project PARSC 010, which was an initial surficial observation of the present-day state of areas where pipeline segments were abandoned in the Alberta Peace River region between 1972 and 1979. The RFP through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

***CH2M Final Report - Review of Previous Pipeline Abandonment Program – TransCanada Peace River Mainline***

In connection with PARSC 010, CH2M completed the project and issued a report in February 2018 titled “CH2M Final Report - Review of Previous Pipeline Abandonment Program – TransCanada Peace River Mainline”. The report described a review of a previous pipeline abandonment program which involved a surface assessment of three 20-inch-diameter pipeline segments of the TransCanada Peace River Mainline (PRML) Pipeline (the Project), abandoned between 1972 and 1979. A total of approximately 12 kilometres of previously abandoned pipeline right-of-way were included in the surface assessment. The Project objective was to review the condition of a medium diameter pipeline that was abandoned more than 10 years ago and includes the following:

- Review the abandonment methodologies implemented at the time of pipeline abandonment;
- Conduct a field surface assessment, to determine if there was evidence of environmental effects or potential environmental effects of pipeline abandonment in-place as currently understood by industry;
- Identify if any environmental effects of pipeline abandonment were in evidence, which were outside of the current industry understanding of the risks of abandonment; and

- Identify areas along the abandoned segments, where subsurface testing could be conducted to further confirm the presence or absence of those potential effects.

Upon investigation, it was determined that formal abandonment plans or details of the abandonment methodologies for the abandoned segments of the PRML proposed for assessment were not available and, as such, this scope of work was removed from the Project. The following objectives were removed from the Project:

- Evaluate the outcomes achieved by the abandonment program
- Develop suggestions for additional testing of the abandoned pipeline to further assess the abandonment program

The abandoned pipeline segments were assessed both from the air, using a helicopter, and by ground-truthing, to determine if there was surficial evidence of the potential environmental effects of pipeline abandonment in-place and to suggest locations where further assessment (that is, subsurface investigation) is recommended to visualize the pipe and surrounding soil for the potential environmental effects described in this report.

The project does not appear to correlate specific abandonment procedures used at each site to the present day subsurface and surface ground effects. However, the project will provide a better understanding of the effects of abandonment in place and support the achievement of the expected results set out in the 2010 "Pipeline Abandonment Scoping Study".


### ***CH2M Proposal - PARSC 015 – Review of Previous Pipeline Abandonment Programs Phase 3***

In connection with PARSC 015, CH2M issued a proposal dated October 6, 2017 for the Review of Previous Pipeline Abandonment Programs Phase 3. The proposed project will research the condition of two 34-inch diameter pipeline segments and their associated right-of-way measuring a total length of approximately 71 km, which were abandoned approximately 30 years ago. An additional segment of Enbridge's mainline right-of-way where the abandoned pipeline was removed will also be assessed as part of the Project. CH2M proposed to evaluate the abandonment program and measure the validity of pipeline abandonment assumptions used in industry today through the PARSC 015 – Review of Previous Pipeline Abandonment Programs Phase 3 Proposal.

The proposed project scope involves the following:

1. Review of the plan designed, approved, and implemented at the time of abandonment and any maintenance activities which have been undertaken on the abandoned line since that time.
2. Visit the sites of the abandonment activities that were undertaken as part of the abandonment plan.
3. Design a future program for additional testing of the abandoned pipeline segments that builds upon the surface observations obtained during the site visits and considers what additional information needs to be obtained to assess the current understanding of pipeline abandonment lifecycles.

The project will involve a review of current ground surface effects of pipelines abandoned approximately 30 years ago. The proposal indicates that the abandonment plan used by the company and any



maintenance activities which have been undertaken on the abandoned line since abandonment will be reviewed. Therefore, it is understood that the abandonment procedures used at each site will be correlated to the ground effects. The information related to abandonment procedures would not be real time. However, the assessed ground effects would be present day. The project is expected to address all recommendations and expected results set out in the 2010 "Pipeline Abandonment Scoping Study", as it relates to evaluating success of previous pipeline abandonment programs.

### ***CH2M Proposal - PARSC 016 – Peace River Abandoned Pipeline Segment Field Study***

In connection with PARSC 016, CH2M issued a proposal dated September 21, 2018 to further investigate the abandonment of pipelines in-place through subsurface assessments and laboratory analysis of segments of the TransCanada Peace River Mainline gas transmission system abandoned between 1972 and 1979, as recommended in PARSC 010.

The proposed project scope involves the following:

1. Perform and document a visual inspection of the pipe, the pipe coating, and any evidence of soil contamination, including photos, at three field work locations.
2. Perform surface visual observations and measurements at 4 Mile Creek, particularly to determine if the pipe is exposed or if exposure is imminent at the river crossing. Observations will be documented with relevant measurements and photos.
3. Arrange for relevant laboratory analyses of the collected pipe coating, soil, and pipe ring samples.
4. Provide a final report summarizing Project activities and outcomes including methodologies and results, analysis and observations, and conclusions.


The proposed project will involve a review of current ground surface and subsurface effects of pipelines abandoned in place between 1972 and 1979. The project does not appear to correlate specific abandonment procedures used at each site to the present day subsurface and surface ground effects. However, the project will provide a better understanding of the effects of abandonment in place and support the achievement of the expected results set out in the 2010 "Pipeline Abandonment Scoping Study".

Collectively, the CH2M report provided in connection with PARSC 010 and the proposals provided in connection with PARSC 015 and 016, address the scope and expected results of the DNV 2010 "Pipeline Abandonment Scoping Study".

### **Conclusion - Addressed**

PARSC issued the following Requests for Proposals:

- PARSC 010 – Review of Previous Pipeline Abandonment Programs
- PARSC 015 - Review of Previous Pipeline Abandonment Programs, Phase 3 – Abandonment on Farmland
- PARSC 016 - Peace River Abandoned Pipeline Segment Field Study [Segment abandoned between 1972 and 1979] dated July 11, 2018.



The Requests for Proposals through the project objective and scope, and through incorporation of the 2010 “Pipeline Abandonment Scoping Study” by reference set out expectations that the scope and expected results of the 2010 “Pipeline Abandonment Scoping Study” would be addressed.

To address the above Requests for Proposals, the following reports and proposals have been provided to PARSC:

- PARSC 010, CH2M Final Report - Review of Previous Pipeline Abandonment Program – TransCanada Peace River Mainline
- PARSC 015 – Review of Previous Pipeline Abandonment Programs Phase 3
- PARSC 016 – Peace River Abandoned Pipeline Segment Field Study

Collectively, the CH2M report submitted in connection with PARSC 010 and the accepted proposals provided in response to PARSC 015 and 016, once completed, should address the scope and expected results of the DNV 2010 “Pipeline Abandonment Scoping Study”.

### 3.13 Collapse of Soil Under Different Void Sizes, Soil Types and Depth of Cover

#### 2010 Recommendation:

The mechanism of soil collapse could be studied in three ways;

- Examine already pulled pipelines to determine actual collapse and magnitude of the resulting surface effect,
- Create voids in soil and accelerate the collapse (this study should examine different pipe sizes, soil types, depths of burial and moisture conditions), and
- Complete model studies using centrifuges.

#### Scope:

The first item could be part of the study of existing abandoned pipelines and involve setting up survey points for multiple year studies to examine the eventual collapse of the soil into the void.

The second study could be to set up a test area with a known soil type and moisture, install a pipeline and compact the soil, later remove the pipe and monitor the collapse depth and timing. Loading by different types of equipment could also be examined in this experimental set-up.

The third suggestion is very similar to that of the second, except that with the use of a centrifuge would allow control of the soil used, pipeline diameters and depth of cover. The tests are conducted on a small-scale basis and the centrifuge is used to determine the long-term effect.

#### Expected Result:

The results of the research will be to develop a model to determine the effects of different soil types and moisture conditions on the potential for soil collapse once a pipeline is pulled out or fails due to corrosion.

#### PARSC Projects to Address Recommendations

No requests for proposal were issued by the PARSC in relation to this recommendation (PARSC – 001).

1 – Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)


#### Analysis

No analysis of the PARSC Proposal was conducted as there were no documents related to PARSC - 001 available as part of this review.

The DNV report is comprised of a literature review followed by detailed analysis of industry research and application of existing principles related to corrosion rates of steel in soils, the collapse mechanisms of soils, and the determination of the suitable structural integrity of buried pipelines. The literature review focused on the following topics:

1. Corrosion Rate of Steels in Soil
2. Structural Integrity of Buried Pipelines





In addition to the literature review, an overview discussion of the mechanisms of corrosion, the soil environment surrounding pipelines, corrosion rates in soil, and a review of the culvert service life predictive models currently developed for vehicle transportation systems.

The report specifically indicates:

- The volume of soil filling the pipeline can be calculated and used to estimate the depth of subsidence at the ground surface.
- A simplified equation to estimate the surface settlement due to the flow of soil into pipeline voids results in a slightly (~10%) non-conservative estimate for most pipe and soil geometries and is recommended for typical pipeline conditions. For larger diameter pipeline (>1m) with depths of cover less than 1m, the non-simplified equation is recommended.
- Note that the equations assume that all soils will flow freely and fill the pipeline void which is inherently conservative.

### **Conclusion – Partially Addressed**

As there was no Request for Proposal available for review for PARSC 001, only the referenced DNV report was reviewed relative to the scope and expected results for this recommendation. Based on the assessment of the DNV report, none of the study scope items were addressed by the findings (e.g., studying existing abandoned pipelines that have been removed by pulling them out without excavation and measure the eventual collapse of soil into the void; install and remove a pipeline in an area of known soil type and moisture and monitor the collapse, including the impacts of loading of surface equipment; and perform scale tests of the collapse of soils into the void left by removed pipe utilizing a centrifuge). The DNV report addressed the expected result of developing a model to determine the effects of different soil types and moisture conditions on the potential for soil collapse once a pipeline is pulled out or fails due to corrosion.

It is anticipated that the remaining scope items identified by the 2010 “Pipeline Abandonment Scoping Study” would constitute an intermediate to significant level of effort to conduct field-based testing, while the initiation of laboratory-based scale testing providing a potential intermediate level of effort to validate the results of the DNV methodology to predict the potential collapse of soil once a pipeline is pulled out or fails due to corrosion.

## 3.14 Validation of Culvert Failure Model for Abandoned Pipelines

### 2010 Recommendation:

The California State Department of Transportation has developed a model for culvert failure from corrosion, which is based on field data for the time to perforation of culverts in various soils in California. The model is very simplistic, incorporating soil pH and resistivity, but is reasonable based on extensive research on the topic over the past century. However, the model has not been validated for thicker structures, such as underground pipelines. Estimates of penetration depth versus time for pipelines are needed, for incorporation in plastic instability models, in order to determine the time of collapse for these structures. The objective of the proposed research is to validate the Culvert Failure Model for the thicker shell walls associated with abandoned pipelines.

### Scope:

The scope of work will be to analyze the extensive underground corrosion data available in the literature and use relevant data to optimize the Culvert Failure Model for general corrosion of the thicker pipeline steels. This model could then be incorporated with an actual collapse model to predict the time to collapse as a function of soil properties and pipeline dimensions.

### Expected Result:

The results of the research will be a validated prediction model for penetration versus time of abandoned pipelines, as a function of soil properties.

### PARSC Projects to Address Recommendations

No requests for proposal were issued by the PARSC in relation to this recommendation (PARSC – 001).

1 – Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)

### Analysis

No analysis of the PARSC Proposal was conducted as there were no documents related to PARSC - 001 available as part of this review.

The DNV report is comprised of a literature review followed by detailed analysis of industry research and application of existing principles related to corrosion rates of steel in soils, the collapse mechanisms of soils, and the determination of suitable structural integrity of buried pipelines. The literature review focused on the following topics:

1. Corrosion Rate of Steels in Soil
2. Structural Integrity of Buried Pipelines

In addition to the literature review, an overview discussion of the mechanisms of corrosion, the soil environment surrounding pipelines, corrosion rates in soil and a review of the culvert service life predictive models currently developed for vehicle transportation systems.

The report specifically indicates:

- It is important to recognize that the culvert models developed and used by the various state DOTs are based on the assumption that the culverts have water and air flowing through them during their service lives. The corrosion of interest is primarily internal corrosion, due to water flow through the culvert, though corrosion may be present on both the internal and external surfaces of the culvert. In the case of abandoned oil and gas pipelines, it is assumed there is minimal water on the inside of the pipeline. If the ends are capped, then no water or air flows. Water may accumulate in pipelines if perforated by corrosion, but this is likely to be a minimal amount and will not occur until many years after the pipeline has been abandoned. There is minimal oxygen present and this restricts the corrosion reactions.
- The corrosion of interest to abandoned pipelines is external corrosion. Pipelines typically have a corrosion resistant coating on the outside, and these coatings may degrade with service and time. However, industry estimates are that the area of disbonded coatings is of the order of one percent of the pipe surface. This means that only one percent of the external surface of the pipe is subject to corrosion. This suggests the culvert models would be extremely conservative if used as life prediction models for pipelines.
- The resulting model combines the determination of the corrosion rate of the abandoned pipeline and its resulting structural integrity to determine a load bearing capacity as a function of time.
- Further development of the models presented is recommended through the field investigation of previously abandoned pipelines to validate the assumptions used in the model development, laboratory testing to further study corrosion rates under disbonded coatings and coating degradation in addition to scale testing to evaluate soil collapse, and the use of finite element modelling to provide predictions to complement the models.

### **Conclusion - Addressed**

As there was no Request for Proposal available for review for PARSC 001, only the referenced DNV report was reviewed relative to the scope and expected results for this recommendation. Based on the assessment of the DNV report, all the study scope items were addressed by the findings (e.g., Validate the Culvert Failure Model for the thicker shell walls associated with abandoned pipelines; and incorporate the validated model into an actual collapse model to predict the time to collapse as a function of soil properties and pipeline dimensions). The DNV report addressed the expected result of the development of a validated prediction model for penetration versus time of abandoned pipelines, as a function of soil properties.

## 3.15 Structural Integrity

### 2010 Recommendation:

API 579-1/ASME FFS-1 provides methods for assessing the fitness for service of pipe with general or local metal loss and external pressure loading that could be applied to abandoned pipelines with external pressure loading from soil.

### Scope:

The methods in API 579-1/ASME FFS-1 may not be directly applicable to pipeline abandonment as written because they were developed for application to pressure vessels and piping in operating facilities. The review should include evaluating whether the fitness-for-service assessment procedures can be tailored directly to pipeline abandonment issues.

### Expected Result:

The research would determine the extent to which they can be applied to abandoned pipelines. A detailed review and evaluation of these methods is needed to assess their applicability to pipeline abandonment issues.

### PARSC Projects to Address Recommendations

*No requests for proposal were issued by the PARSC in relation to this recommendation (PARSC – 001).*

*1 – Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)*

### Analysis

No analysis of the PARSC Proposal was conducted as there were no documents related to PARSC - 001 available as part of this review.

The DNV report is comprised of a literature review followed by detailed analysis of industry research and application of existing principles related to corrosion rates of steel in soils, the collapse mechanisms of soils, and the determination of suitable structural integrity of buried pipelines. The literature review focused on the following topics:

1. Corrosion Rate of Steels in Soil
2. Structural Integrity of Buried Pipelines

In addition to the literature review, an overview discussion of the mechanisms of corrosion, the soil environment surrounding pipelines, corrosion rates in soil and a review of the culvert service life predictive models currently developed for vehicle transportation systems.

The report specifically indicates:

- The objective of the structural integrity modelling is to determine the load bearing capacity of the pipeline as a function of corrosion damage. As a pipeline corrodes, the wall thickness decreases or the pipeline becomes perforated, and this changes the pipeline's load bearing capacity. The load bearing capacity will therefore change with time. It is possible to determine the critical surface load necessary to cause collapse for a given pipe geometry



and soil conditions. In combination with the corrosion rate modelling, it is possible to determine the critical surface load as a function of time, or the time to collapse due to soil weight alone.

- The assessment process considers both soil loads and live loads (surface loads) and their effect on the failure of the pipeline through plastic and/or elastic collapse mechanisms.
- The modelling process involves the following steps:
  - 1- Compilation of data = pipe characteristics, burial conditions, soil conditions and the time interval of interest.
  - 2- Determination of corrosion conditions = coated vs uncoated pipe
  - 3- Determination of wall thickness at the time of interest = based on the prediction of corrosion
  - 4- Determination of soil loads action on the pipe
  - 5- Determination of critical loads = known live loads and/or the determination of the load bearing capacity of the pipe.
- The resulting model combines the determination of the corrosion rate of the abandoned pipeline and its resulting structural integrity to determine a load bearing capacity as a function of time.
- Further development of the models presented is recommended through the field investigation of previously abandoned pipelines to validate the assumptions used in the model development, laboratory testing to further study corrosion rates under disbonded coatings and coating degradation in addition to scale testing to evaluate soil collapse, and the use of finite element modelling to provide predictions to complement the models.

### **Conclusion - Addressed**

As there was no Request for Proposal available for review for PARSC 001, only the referenced DNV report was reviewed relative to the scope and expected results for this recommendation. Based on the assessment of the DNV report, the study scope item was addressed by the findings (e.g., the evaluation of whether the fitness-for-service assessment procedures can be tailored directly to pipeline abandonment issues.). The DNV report addressed the expected result of determining the extent to which the fitness-for-service assessment procedures can be applied to abandoned pipelines.



## **APPENDIX I**

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### **PARSC Document Inventory - Evaluation**

<b>Evaluation</b>		NOTES: * Where a final report has not yet been issued, the successful proposal was reviewed to determine if the project, as proposed would address the scope and expected results of the DNV Scoping Study.  ** In some cases, the Request for Proposals (RFP) did not specifically address the individual criterion in the scope or objective, but did incorporate the DNV Scoping Study by reference in the RFP. In such cases, the RFP was deemed to have partially addressed the criterion for scope or expected result.	
<b>1. DETECTION OF RESIDUAL CONTAMINATION</b>			
<b>Documents Reviewed:</b> 1 - Request for Proposals - PARSC 005 - Standard Pipeline Products List and Detection of Residual Contamination in Abandoned Pipelines (July 16, 2014) 2 - Alberta Innovates - Technology Futures Report for PARSC 004 and 005 - Cleaning of Pipelines for Abandonment (September 2015)			
<b>Criteria for Scope &amp; Expected Result</b>		<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Have standard testing protocols been developed in consideration of standard practices for detection of hydrocarbons, PCBs and NORMs in pipelines?		1 - Addressed	2 - Not Addressed
S2. Has a study been conducted on Methods to accurately quantify residual hydrocarbons along an abandoned pipeline?		1 - Addressed	2 - Not Addressed
S3. Have standard practices for detection of PCBs where suspected in abandoned pipelines been studied and developed?		1 - Partially Addressed**	2 - Not Addressed
S4. Have standard practices for detection of NORM-contaminated pipe been developed?		1 - Partially Addressed**	2 - Not Addressed
E1. Does the standard testing protocol lead to the following? <ul style="list-style-type: none"> <li>• An accurate indication of the potential concentrations of contaminants to be transported down a section of abandoned pipeline as a result of the conduit effect;</li> <li>• A greater understanding of the nature, extent and distribution of contaminants, which is the first step in developing formal risk assessment tools modelling the fate and effects of detected contaminants in an abandoned pipeline;</li> <li>• Consistent results, allowing statistical studies of such results to be compiled from various abandonment projects and, over time, lead to the development of a contaminant database with the establishment of categories of expected residual contaminants based on the pipeline product and locations along the pipeline system;</li> <li>• Greater support for providing an indication of effective cleaning methods; and</li> <li>• Guidance for decision making on locations for pipeline abandonment in-place.</li> </ul>		1 - Partially Addressed**	2 - Not Addressed

<b>2. IDENTIFY COMPOUNDS TO BE TESTED FOR IN SOIL AND WATER</b>		
<b>Documents Reviewed:</b> None		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. A review of products shipped through NEB regulated pipeline systems.	Not Assessed. No RFP Issued.	Not Assessed. No RFP Issued.
E1. The development of a standard list of compounds expected to be found as a result of a pipeline leak.	Not Assessed. No RFP Issued.	Not Assessed. No RFP Issued.
<b>3. RISK ASSESSMENT</b>		
<b>Documents Reviewed:</b> <b>1 - Request for Proposals - PARSC 008 – Risk-Based Decision Making Framework for Pipeline Abandonment (March 22, 2016)</b> <b>2 - Arcadis - Risk-Based Decision Making Framework for Pipeline Abandonment (Final) - A Guide for Evaluating Risks Associated with Physical and Technical Hazards Related to Abandonment-In-Place (November 2, 2018)</b> <b>3 - Usability Review of a Guide for Evaluating Pipeline Abandonment Risks</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Does the research identify the various scenarios and related consequences of pipeline abandonment events and identify potential consequences of those events?	1 - Addressed	2 - Addressed
E1. Does the research determine the potential risk exposure for various events and outline potential safeguards to reduce the frequency and/or consequences of a particular event?	1 - Addressed	2 - Partially addressed
<b>4. CONDUIT EFFECT</b>		
<b>Documents Reviewed:</b> <b>1 - Request for Proposals - PARSC 012 – Water Conduit Effect in Abandoned Pipelines (March 21, 2016)</b> <b>2 - AMEC - Water Conduit Effect in Abandoned Pipelines (August 2017)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
No further research was recommended as part of the Pipeline Abandonment Study, although PARSC did issue an RFP on this subject.	Addressed. No Research Recommended.	2 - Addressed
<b>5. DECOMPOSITION OF PIPE MATERIAL</b>		



Documents Reviewed: 1 - Request for Proposals - PARSC 006 - Decomposition of Pipe Coating Materials in Abandoned Pipelines (July 16, 2014) 2 - Nova Chemicals - Fate and Decomposition of Pipe Coating Materials in Abandoned Pipelines (July 3, 2015)		
Criteria for Scope & Expected Result	Request for Proposal	Proposal* / Report
S1. Has leaching potential and associated human health and environmental effects of the contaminants released from coal tar coatings been studied?	1 - Addressed	2 - Addressed
S2. Has a theoretical understanding of the potential for leached contaminants to move through various soil and groundwater regimes, as well as the human and environmental consequences of such contamination been established?	1 - Addressed	2 - Addressed
S3. Has laboratory testing of the structural integrity and the rate and nature of chemical decomposition of coal tar coatings under simulated field conditions been undertaken?	1 - Addressed	2 - Not Addressed
E1. Does the study provide a greater understanding of the nature and rate of coal tar wrap decomposition, dispersal of leached chemicals in the surrounding environment and the potential human and environmental effects of leached contaminants?	1 - Addressed	2 - Addressed
E2. Does the study contribute to the development of formal risk assessment models with respect to identifying the fate and effects of detected contaminants in an abandoned pipeline with coal tar coating?	1 - Partially Addressed**	2 - Not Addressed
E3. Does the study result in the establishment of safe handling and disposal procedures / recycling options for pipelines coated with coal tar wrap?	1 - Partially Addressed**	2 - Not Addressed
<b>6. CLEANING METHODS AND DISPOSAL OF CLEANING FLUIDS</b>		

**Documents Reviewed:**

**1 - Request for Proposals PARSC 004 – Cleaning Methods for Abandoned Pipelines (July 16, 2014)**

**2 - Request for Proposals PARSC 007 - Recommended Practice for Cleaning Pipelines for Abandonment – Stage 1 (March 22, 2016)**

**3 - Alberta Innovates - Technology Futures Report for PARSC 004 and 005- Cleaning of Pipelines for Abandonment (September 2015)**

**4 - DNV GL Proposal for PARSC 007 – Recommended Practice for Cleaning Pipelines for Abandonment (April 14, 2016)**

Criteria for Scope & Expected Result	Request for Proposal	Proposal* / Report
S1. Will an engineer led study be undertaken to determine effective cleaning methods in an attempt to determine cleanliness parameters for either abandoning pipeline in place or removing sections for reuse or disposal?	1 - Addressed 2 - Addressed	3 - Not Addressed 4 - Addressed
E1. Does the study establish safe handling and disposal methods for pipelines?	1 - Partially Addressed** 2 - Not Addressed	3 - Not Addressed 4 - Not Addressed
E2. Does the study provide an indication of the effectiveness of cleaning operations along a given length of pipeline?	1 - Addressed 2 - Addressed	3 - Addressed 4 - Addressed
E3. Does the study remove the obscurity in determining "how clean is clean" and streamline the abandonment process in a safe and responsible manner?	1 - Partially Addressed** 2 - Not Addressed	3 - Not Addressed 4 - Addressed

E4. Does the study determine the environmental suitability of the cleaning compounds?	1 - Partially Addressed** 2 - Not Addressed	3 - Addressed 4 - Addressed
E5. Does the study address handling and disposal of wax, waste petroleum products, spent cleaning compounds, etc.?	1 - Partially Addressed** 2 - Not Addressed	3 - Not Addressed 4 - Not Addressed
E6. Does the study address the environmental safety of all practices (risk of spills, emergence preparedness, worker and public health, etc.)?	1 - Partially Addressed** 2 - Not Addressed	3 - Not Addressed 4 - Not Addressed
E7. Does the study develop achievable cleanliness standards for pipe to be abandoned in place or removed for reuse or disposal?	1 - Partially Addressed** 2 - Not Addressed	3 - Not Addressed 4 - Addressed
<b>7. DISPOSAL OF PIPE MATERIAL</b>		
<b>Documents Reviewed: None</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>

Until standards have been developed to determine acceptable concentrations of residual contaminants, recommendations for reuse and/or disposal studies cannot be made.	Not Assessed. No RFP Issued.	Not Assessed. No RFP Issued.
<b>8. ABANDONMENT UNDER WATER BODIES</b>		
<b>Documents Reviewed:</b> <b>1 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios (May 30, 2017)</b> <b>2 - Matrix Solutions Inc. – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, for PARSC 013, Version 2.0 (August 2018)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Have engineering field tests to determine the diameter and length of pipelines and the extent to which they can be pulled from the ground should been conducted?	1 - Partially Addressed**	2 - Not Addressed
S2. Did the project address potential environmental effects associated with pulling pipe from underneath water bodies including alterations of stream hydrology as a result of subsidence and structural instability of the bed and bank complex?	1 - Addressed	2 - Not Addressed
S3. Did the project address potential environmental effects associated with pulling pipe from beneath sensitive ecological areas and wetlands including subsidence and terrain instability, as well as channeling of surface and subsurface water along the trench and associate subsidence and/or erosion?	1 - Addressed	2 - Not Addressed

E1. Does the study establish mitigation measures in response to potential environmental effects associated with pulling pipe from under water bodies and sensitive ecological areas?	1 - Addressed	2 - Not Addressed
E2. Does the study establish best-practices for abandoning a section of pipeline under a water body or sensitive ecological area?	1 - Addressed	2 - Not Addressed
9. COMPILE EXPOSURE DATA FROM NEB AND ERCB RECORDS		
<b>Documents Reviewed:</b> <b>1 - Request for Proposals - PARSC 013 - Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios (May 30, 2017)</b> <b>2 - Matrix Solutions Inc. – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, for PARSC 013, Version 2.0 (August 2018)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Did the research expand the database by compiling an updated list of exposure instances?	1 - Addressed	2 - Not Addressed
S2. Have the GIS and NEB/ERCB records correlated exposures with hydrotechnical, geotechnical and wind erosion hazards (this would include third party damages due to reduced depth of cover) where possible?	1 - Addressed	2 - Not Addressed

E1. Does the study help guide the committee to understand the sites most at risk due to exposure, and where exposure is unlikely?	1 - Addressed	2 - Addressed
<b>10. EXAMINE BUOYANCY EFFECTS ON PIPELINE EXPOSURE RATES</b>		
<b>Documents Reviewed:</b>		
1 - Request for Proposals - PARSC 013 –Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios (May 30, 2017)		
2 - Matrix Solutions Inc. – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios, for PARSC 013, Version 2.0 (August 2018)		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Study the longevity of different buoyancy control measures.	1 - Addressed	2 - Addressed
E1. Develop a model that could be used to predict the potential for and the timing of exposure of abandoned pipelines due to lack of or loss of buoyancy control	1 - Partially Addressed**	2 - Not Addressed
<b>11. EXAMINE FROST HEAVE EFFECTS ON PIPELINE EXPOSURE RATES</b>		
<b>Documents Reviewed:</b>		
1 - Project Description - Letter of Interest Request - PARSC 003 - Frost Heave Effects on Pipeline Exposure Rates (July 9, 2013)		
2 - Request for Proposals - PARSC 013 – Analysis of Pipeline Exposure Data and Scoping Review of Exposure Scenarios (May 30, 2017)		
3 - Matrix Solutions Inc. - Analysis Of Pipeline Exposure Data And Scoping Review Of Exposure Scenarios		
4 - Stantec Consulting Ltd. - 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– November 3, 2014)		
5 - Stantec Consulting Ltd. 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 2 (Appendices - November 3, 2014)		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Understand the mechanism of heaving of abandoned pipelines	1 - Addressed, 2 - Partially Addressed**	3 - Addressed 4/5 - Addressed

S2. A laboratory study to examine, under multiple freeze thaw cycles, the interaction of growing ice under the pipeline against resistance forces above the pipeline.	1 - Partially Addressed** 2 - Partially Addressed**	3 - Partially Addressed 4/5 - Partially Addressed
S3. Compare the laboratory results to field studies to better understand the effect of frost heave on long segments of pipeline.	1 - Partially Addressed** 2 - Partially Addressed**	3 - Not Addressed 4/5 - Not Addressed
E1. Does the research develop a numerical model to determine the effects of different soil types and moisture conditions on the potential for an abandoned pipeline to become jacked out of the ground by frost action	1 - Partially Addressed** 2 - Partially Addressed**	3 - Not Addressed 4/5 - Addressed
E2. Was a field study conducted on suspended pipelines or ambient temperature product pipelines to provide real scale information related to local frost heave effects on a long section of pipeline	1 - Partially Addressed** 2 - Partially Addressed**	3 - Not Addressed 4/5 - Not Addressed
<b>12. EVALUATE SUCCESS OF PREVIOUS PIPELINE ABANDONMENT PROGRAMS</b>		
<b>Documents Reviewed:</b> <b>1 - Request for Proposals - PARSC 010 – Review of Previous Pipeline Abandonment Programs (September 16, 2016)</b> <b>2 - Request for Proposals - PARSC 015 - Review of Previous Pipeline Abandonment Programs, Phase 3 – Abandonment on Farmland (August 28, 2017)</b> <b>3 - Request for Proposals - PARSC 016 - Peace River Abandoned Pipeline Segment Field Study [Segment abandoned between 1972 and 1979], (July 11, 2018)</b> <b>4 - CH2M Final Report - PARSC 010 – Review of Previous Pipeline Abandonment Program – TransCanada Peace River Mainline (February 2018)</b> <b>5 - CH2M Proposal - PARSC 015 – Review of Previous Pipeline Abandonment Programs Phase 3 (October 6, 2017)</b> <b>6 - CH2M Proposal - PARSC 016 – Peace River Abandoned Pipeline Segment Field Study (September 21, 2018)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Has/will “real time” information been compiled with respect to actual procedures used for pipeline abandonment?	1 - Not Addressed 2 - Addressed 3 - Not Addressed	4 - Not Addressed 5 - Addressed 6 - Not Addressed

S2. Does/will the scope of the project cover abandoned pipelines under NEB or ERCB jurisdiction?	1 - Addressed 2 - Addressed 3 - Addressed	4 - Addressed 5 - Addressed 6 - Addressed
S3. Has/will a report been/be assembled detailing the approaches taken for each site?	1 - Addressed 2 - Addressed 3 - Not Addressed	4 - Not Addressed 5 - Addressed 6 - Not Addressed
S4. Does/will the report include the study of the current ground surface effect of pipelines that are abandoned in place?	1 - Addressed 2 - Addressed 3 - Addressed	4 - Addressed 5 - Addressed 6 - Addressed



S5. Does/will the report include the study of the current ground surface effects of pipelines that have been removed?	1 - Partially Addressed** 2 - Addressed 3 - Not Addressed	4 - Not Addressed 5 - Addressed 6 - Not Addressed
E1. Will the results of the research will provide a better understanding of the effects of actual abandonment procedures?	1 - Addressed 2 - Addressed 3 - Addressed	4 - Addressed 5 - Addressed 6 - Addressed
<b>13. COLLAPSE OF SOIL UNDER DIFFERENT VOID SIZES, SOIL TYPES AND DEPTH OF COVER</b>		
<b>Documents Reviewed:</b> No RFP documents related to PARSC - 001 were available as part of this review. <b>1 - Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Study existing abandoned pipelines that have been removed by pulling them out without excavation and measure the eventual collapse of soil into the void.	Not Assessed	1 - Not Addressed
S2. Install and remove a pipeline in an area of known soil type and moisture and monitor the collapse, including the impacts of loading of surface equipment.	Not Assessed	1 - Not Addressed
S3. Perform scale tests of the collapse of soils into the void left by removed pipe utilizing a centrifuge.	Not Assessed	1 - Not Addressed

E1. Develop a model to determine the effects of different soil types and moisture conditions on the potential for soil collapse once a pipeline is pulled out or fails due to corrosion.	Not Assessed	1 - Addressed
<b>14. VALIDATION OF CULVERT FAILURE MODEL FOR ABANDONED PIPELINES</b>		
<b>Documents Reviewed:</b> No RFP documents related to PARSC - 001 were available as part of this review.		
<b>1 - Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. Validate the Culvert Failure Model for the thicker shell walls associated with abandoned pipelines	Not Assessed	1 - Addressed
S2. Incorporate the validated model into an actual collapse model to predict the time to collapse as a function of soil properties and pipeline dimensions.	Not Assessed	1 - Addressed
E1. The development of a validated prediction model for penetration versus time of abandoned pipelines, as a function of soil properties	Not Assessed	1 - Addressed
<b>15. STRUCTURAL INTEGRITY</b>		
<b>Documents Reviewed:</b> No RFP documents related to PARSC - 001 were available as part of this review.		
<b>1 - Det Norske Veritas Final Report - Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (March 5, 2015)</b>		
<b>Criteria for Scope &amp; Expected Result</b>	<b>Request for Proposal</b>	<b>Proposal* / Report</b>
S1. The review should evaluate whether the fitness-for-service assessment procedures can be tailored directly to pipeline abandonment issues.	Not Assessed	1 - Addressed
E1. Determine the extent to which the fitness-for-service assessment procedures can be applied to abandoned pipelines. A detailed review and evaluation of these methods is needed to assess their applicability to pipeline abandonment issues	Not Assessed	1 - Addressed



## About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil & gas and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our professionals are dedicated to helping our customers make the world safer, smarter and greener.