



**WATER CONDUIT EFFECT IN ABANDONED
PIPELINES PIPELINE ABANDONMENT RESEARCH
STEERING COMMITTEE PARSC 012**

REPORT

Submitted to:

Petroleum Technology Alliance Canada
Calgary, Alberta

Submitted by:

Amec Foster Wheeler Environment & Infrastructure
Edmonton, Alberta

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EXECUTIVE SUMMARY

The Petroleum Technology Alliance Canada retained Amec Foster Wheeler Environment & Infrastructure to conduct a Water Conduit Effect in Abandoned Pipelines study that included a literature review (Task 1), scenario identification (Task 2) and identification of potential mitigations (Task 3).

Water conduits are defined by the Pipeline Abandonment Steering Committee of the National Energy Board as:

“A channel for conveying water. In the context of pipeline abandonment or decommissioning, refers to a pipeline that has become corroded and perforated and transports ground or surface water to a different location.”¹¹

A total of seventy-nine (79) sources of possible information were reviewed for real world examples and theoretical scenarios concerning water conduits in abandoned pipelines. No historical instances of water conduit formation in pipelines were found in the literature search, but research indicated that it remains a potential concern for pipeline abandonment. While several theoretical water conduit scenarios have been proposed, an understanding of the requisite conditions for water conduit formation in real-life applications has yet to be adequately established. Based on our understanding of the water conduit effect, the most likely scenarios involve: Contaminated Sites, Inclines, Recharging Water Bodies (rivers, lakes, oceans), and Small Water Body (wetlands, sloughs). The above four scenarios, are described and specific mitigation measures and management options to address them are made.

Amec Foster Wheeler notes that, given the predicted corrosion of pipelines is a long term process ^{1B}, there is considerable time to develop a more complete understanding of water conduits before implementing mitigation.

Some studies have taken the approach that the risks associated with water conduit formation should be addressed at the time of abandonment (i.e. mitigation and management practices are carried out at that time); however, it may also be appropriate to assign a liability based on best mitigation practices like those in the table, but delay implementation of mitigations measures until a better understanding of water conduits formation is acquired.

¹ Pipeline Abandonment Steering Committee (PASC). Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues (1996). Website: <http://www.neb-one.gc.ca/prtcptr/pplnbndnmnt/pplnbndnmnttchnclnvrnmntl-eng.html>. Accessed June 21, 2016

^{1B} Det Norske Veritas. Understanding the Mechanisms of Corrosion and their Effects on Abandoned Pipelines (2015). Website: <https://www.ptac.org/wp-content/uploads/2016/08/DNV-Final-Report-PTAC-PARSC-001-Rev1-PP079627-March-3-2015.pdf>.

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PART 1 Task 1 – Literature Review

1.0 INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler) is submitting this report in accordance with the agreed upon scope of work with Petroleum Technology Alliance Canada (PTAC) to address possible risks associated with the water conduit effect and potential related environmental impacts in relation to abandoned pipelines.

1.1 PROJECT BACKGROUND

For pipelines abandoned in place, the issue of water conduits is a potential concern.

The Pipeline Abandonment Steering Committee defined **water conduits** in their 1996 paper entitled “Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues” as:

“A channel for conveying water. In the context of pipeline abandonment or decommissioning, refers to a pipeline that has become corroded and perforated and transports ground or surface water to a different location.”²

A variety of plausible environmental effects focusing on the movement of water into and out of perforated abandoned pipelines have been proposed. These impact scenarios can be divided into three major groups: 1. Impacts to wetlands and other nearby environmentally-sensitive features due to water conduits changing the pre-existing hydrological and/or hydrogeological regimes. 2. Ecological impacts associated with the entrainment of contamination from the abandoned pipeline; and 3. Ecological impacts associated with entrainment of contamination or sediment external to the abandoned pipeline. While several theoretical scenarios of risks due to water conduit scenarios have been proposed, an understanding of the requisite conditions for water conduit formation in real-life applications has yet to be adequately established. Understanding the prevalence and magnitude of risks of water conduit formation is a crucial aspect of pipeline abandonment that needs to be properly addressed.

This study was commissioned to review the existing publicly-available body of knowledge on water conduits within abandoned pipelines including: assessing what risks are addressed in regulatory guidance for pipeline abandonment, examining potential environmental impacts of water conduits, and reviewing implementation of appropriate mitigation measures for those risks, including, but not limited, to physical segmentation.

1 Pipeline Abandonment Steering Committee (PASC). Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues (1996). Website: <http://www.neb-one.gc.ca/prtcptn/pplnbndnmnt/pplnbndnmnttchnclnvrmmntl-eng.html>. Accessed June 21, 2016. PASC was comprised of representatives from the Canadian Association of Petroleum Producers, the Canadian Energy Pipeline Association, the Alberta Energy and Utilities Board (now Alberta Energy Regulator), and the National Energy Board).

2 NEB - Pipeline Abandonment, A Discussion Paper on Technical and Environmental Issues, November 1996. CAPP.

The 1996 NEB Discussion paper identified water conduits as a potential environmental concern. To date, no situations of water conduit have been reported or identified, therefore the focus of this paper is on the theoretical scenarios which could lead to water moving from one location to another through an abandoned pipeline.

2.0 SCOPE OF REVIEW

This study was prepared for the Petroleum Technology Alliance of Canada and covers the requirements of PTAC's Pipeline Abandonment Research Steering Committee (PARSC): PARSC 012 – Water Conduit Effects in Abandoned Pipelines (copy provided in Appendix A). This draft report documents the results of the first of three tasks agreed upon in the scope of work developed by Amec Foster Wheeler in conjunction with PTAC.

The scope of this draft report is to document activities associated with Task 1 consisting of a literature search and analysis for the previous 15 years for:

- enacted regulations for abandonment applicable to water conduit formation;
- industry standards or best practices concerning pipeline abandonment and strategies to mitigate the risk of water conduit formation;
- theoretical scenarios and actual examples of water conduit formation and identified environmental impacts; and
- theoretical and applied mitigation measures for water conduits.

In accordance with the agreed upon scope of work, Amec Foster Wheeler has scrutinized the current, available, English language, knowledge base using internet search techniques to determine where, if any, water conduits have historically been identified in publicly available records, their effect, and what mitigation strategies have been or could be employed to address them. The project aimed to distinguish between actual case studies and theoretical considerations of the water conduit effect.

3.0 METHODOLOGY

The research methodology for this review was through English literature searches from publicly available records including: regulations, industry reports, conference and journal technical papers, government agencies publications, and other open sources. Sources included Canadian Government (federal, provincial and territorial) databases for items relevant to the water conduit effect in abandoned pipelines. This included regulatory bodies such as the National Energy Board (NEB). Other government agencies' databases in English speaking countries with significant pipeline infrastructure (e.g. USA and Australia) were also researched. A review of industry association publications (e.g. Canadian Alliance of Petroleum Producers (CAPP), Canadian Energy Pipeline Association (CEPA), Petroleum Technology Alliance (PTAC), American Pipeline Institute (API), and AOPL (Association of Oil Pipe Lines) was also undertaken. All searches were electronic or "on-line".

Sources were limited to those that provided specific information concerning abandonment, idling, decommissioning or de-activation activities in which the risk for water conduit formation within

pipelines was specified as an area of concern. The summary does not make any claim that the summary is comprehensive for all aspects of abandonment.

Terms used to describe pipeline states pertinent to this review include - discontinued, deactivated, deactivated, idled, decommissioned, abandoned or any derivatives of the associated root words. For the purposes of this report, the term “abandoned” will be used to represent all pipelines which are left *in situ* and no longer contain product (unless quoting from an original source). In consideration of the above, the abandoned pipeline may or may not be maintained by any combination of measures including but not limited to - application of cathodic protection, pigging, application of a nitrogen blanket, cut and capping, signage or abandoned with no measures.

Searches were completed for conduits affecting abandoned pipelines in any application (water, natural gas, diluent, oil) with the notable exceptions of sewer pipeline and for off-shore facilities. Water conduit effects within sewer lines were not considered applicable to the review as they are designed to transmit fluids downgradient, are frequently constructed with different materials than oil and gas pipelines, and are sloped (constructed to encourage water movement without pumping). The processes considered in sewer pipeline construction were considered sufficiently divergent from oil and gas pipelines to invalidate their applicability for this review.

While there is additional literary material associated with offshore decommissioning of pipelines, a review of their risks in terms of water conduits was not considered warranted. Specifically water is expected to fill a submerged perforated pipeline until the water pressure within the pipeline is at equilibrium with the pressure of the surrounding water at any point within the pipeline, precluding the possibility of water movement.

4.0 SCOPE AMENDMENT

In the original scope of work an assessment of all available records concerning water conduit formation was to be limited to the last 15 years (i.e. from 2001). Given the lack of accessed content the search was expanded to include any accessible records that directly or indirectly referred to water conduits in pipelines and included the results of regulatory hearings and applications in which water conduit issues had been brought forward.

5.0 RESULTS

A total of seventy-nine sources of possible information were reviewed for theoretical scenarios and real world examples concerning water conduits in abandoned pipelines. A listing of the reviewed sources is contained in Appendix B.

In summary, the following points were consistent in the review of the accessed documents and together should be evaluated for further consideration:

- The theoretically possible risks and implications of water conduits were cited in most if not all of the accessed literature; however, no verified “real world” examples of water conduit formation for abandoned pipelines were discovered from any source. This is consistent with the finding of the 2010 Det Norske Veritas³ assessment. One reviewed article⁴ of environmental considerations associated with abandonment of a pipeline specifically discussed measures to mitigate the effects of water conduits, however in that instance it was not clear if water conduit formation had been observed or if the measures were put in place to deal with theoretical considerations.
- Water conduits were first identified as a possible risk for abandoned pipelines in the 1996 Discussion paper “Pipeline Abandonment - A Discussion Paper on Technical and Environmental Issues”⁵ prepared for the Pipeline Abandonment Steering Committee (PASC). PASC was comprised of representatives from the Canadian Association of Petroleum Producers, the Canadian Energy Pipeline Association, the Alberta Energy and Utilities Board (now Alberta Energy Regulator), and the National Energy Board).

It could not be ascertained if the risk for water conduits discussed within the paper was identified from a previous information source or if the discussion within the paper was formulated through risk analysis by the authors, based on industry experience.

- Since 1996, with few exceptions, literature reviewed either cited the above referenced NEB Discussion paper, or cited a paper, which had reviewed that paper concerning possible water conduit effects and possible appropriate mitigation measures.

5.1 SUMMARY OF REFERENCES OF NOTE:

The 1996 Pipeline Abandonment Steering Committee - Pipeline Abandonment Discussion Paper

The 1996 NEB Pipeline Abandonment Discussion Paper explains the theoretical water conduit effect extensively in Section 3.9 Creation of Water Conduits. It includes the following table in which the general locations where pipeline segmentation (plugging) was suggested to address water conduit formation risks.

³ Det Norske Veritas. 2010. Pipeline Abandonment Scoping Study. Prepared for the National Energy Board, Report No. EP028844. 85 pp.

⁴ J. Swanson, T. Kunicky and P. Pookhay. 2010. Environmental Considerations For Pipeline Abandonment of a Southern Alberta Pipeline.

⁵ Pipeline Abandonment Steering Committee. 1996. Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues. Website: <http://www.neb-one.gc.ca/prtcptr/pplnbndnmnt/pplnbndnmntchnclnvrmmntl-eng.html>. Accessed June 21, 2016.

Table 3-1	
Recommended Plug Locations	
Terrain Feature	Plug Locations
waterbodies/watercourses	above top of bank
long inclines (>200 m), river banks	at top and bottom of slope and at mid-slope for long inclines
flood plains	at boundaries
sensitive land uses (e.g. natural areas, parks)	at boundaries
near waterfalls, shallow aquifers, groundwater discharge and recharge zones, marshes, sloughs, peatlands, high water table areas	at boundaries and should include an adequate buffer zone
cultural features (population centres)	at boundaries

From: Pipeline Abandonment Steering Committee. 1996. Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues.

CEPA (2007) ⁶ reviewed the above material and agreed the locations specified in the aforementioned table “remain valid today”.

The Det Norske Veritas Pipeline Abandonment Scoping Study

The 2010 Det Norske Veritas (DNV) Scoping Study ⁷ reviewed the material on water conduits and was in agreement with the NEB Discussion Paper and CEPA (2007). DNV was further of the opinion that based on their review risks of water conduits and the locations for segmentation “is understood and manageable”. The DNV Scoping Study did not recommend additional work regarding water conduits effects, although it did suggest monitoring for the phenomenon as part of future anticipated studies to evaluate the success of previous pipeline abandonment programs.

⁶ Canadian Energy Pipeline Association. 2007. Pipeline Abandonment Assumptions: Technical and Environmental Considerations for Development of Pipeline Abandonment Strategies. Prepared for the Terminal Negative Salvage Force of the Canadian Energy Pipeline Association. 85 pp.

⁷ Det Norske Veritas. 2010. Pipeline Abandonment Scoping Study. Prepared for the National Energy Board, Report No. EP028844. 85 pp.

The Canadian Standards Association - CSA Z662: Oil and Gas Pipeline Systems

CSA Z662 provides guidance to Canadian industry concerning Oil and Gas Pipeline Systems. Section 10.16.2 specifically discusses appropriate measures associated with abandoning onshore pipelines in place. The standards are consistent with, or more stringent than corresponding Australian, American, Thai and United Kingdom guidelines accessed and reviewed. A copy of the relevant portions of the CSA (2015) text is provided below.

10.16 Abandonment of pipelines and pipe-type storage vessels

10.16.1 General

The decision to abandon a section of a pipeline, whether in place or through removal, shall be made on the basis of a documented abandonment plan that includes the rationale for the abandonment, landowner consultation, effect on terrain and water, road and railway crossings, as well as current and potential land use. The plan shall consider the potential for safety hazards and environmental damage that could be created by ground subsidence, soil admixing or contamination, groundwater contamination, erosion, and the creation of water conduits.

Note: The NEB Pipeline Abandonment: A Discussion Paper on Technical and Environmental Issues, National Energy Board, Section 2 provides guidance.

Section 10.16.2 Buried pipelines

A buried pipeline that is abandoned in place shall be:

- (a) emptied of service fluids;*
- (b) purged or appropriately cleaned or both in a manner that leaves no mobile materials remaining in the pipeline;*
- (c) physically separated from any in-service piping;*
- (d) capped, plugged, or otherwise effectively sealed;*
- (e) cut off at pipeline depth; and*
- (f) left unpressurized.*

From: 2015 CSA Z662: Oil and gas pipeline systems (2015)

The CSA Standard specifies that water conduits should be addressed as part of the overall abandonment plan. However, apart from indicating that the abandoned pipelines should be effectively sealed, the CSA Standard does not recognize any particular additional measures that are required to prevent water conduit formation or provide justification for the measures required. The CSA Standard notes that the methods and considerations for abandonment discussed in the 1996 Discussion Paper should be referenced to provide guidance on abandonment.

5.2 RESULTS SUMMARY

The literature search did not provide any record of water conduit formation having occurred in abandoned pipelines.

Applicable regulations and standards in Canada and Internationally generally specify that risks for water conduits should be addressed in case of abandonment. Guidance consistently specifies when developing an abandonment plan that operators are to disconnect the pipeline from active systems; however, it is not clear if the disconnection is to remove possible risks for inadvertent product release into abandoned systems, to provide effective compliance definition, or to address water conduit formation. Regulations do not specify how possible water conduit risks are to be addressed however they do list possible mitigation measures to be considered.

The most comprehensive set of recommendations remains the treatment provided in the 1996 PASC Discussion paper and in particular as prescribed within Table 3-1. It could not be ascertained if the source of the PASC recommendations, in particular if the conclusions were based on previous experience with abandonment projects or limited to theoretical risk analysis.

6.0 CONCLUSION

An online literature search did not reveal any reported cases of water conduit formation in pipelines. It was anticipated that by finding an example of water conduit formation, the requisite conditions for their formation could be better understood. While no instances of water conduit formation in practice were cited, the Precautionary Principle requires that mitigation for environmental risks for water conduits for abandoned pipelines should still be considered.

Regulators, operating companies and environmental clean-up service companies were not directly surveyed or contacted for evidence of water conduit formation, as those tasks were beyond the specified scope of this study.

6.1 POTENTIAL WATER CONDUIT SCENARIOS:

As proposed in the original scope of work and based on the results of the literature review, the most likely scenarios regarding the water conduit effect and its impacts were to be assessed.

The following four identified theoretical water conduit formation scenarios are explored within Part 2 of this study:

1. Contaminated Sites
2. Inclines
3. Recharging Water Body (rivers, lakes, oceans)
4. Small Water Body (wetlands, sloughs)

6.2 POTENTIAL MITIGATION MEASURES:

Based on the understanding of the water conduit effect, specific mitigation measures are addressed in Tasks 2 and 3 in Part 2 of the study.

6.2.1.1.1.1 PART 2 Task 2 - Scenario Development, and Task 3 - Mitigation Options

7.0 LITERATURE REVIEW SUMMARY (FROM PART 1)

This study follows a previously conducted literature review of existing publicly-available body of knowledge on water conduits within abandoned pipelines (Final report dated 17 April 2017, “PTAC - Petroleum Technology Alliance Canada, PARSC 012 – Water Conduit Effect in Abandoned Pipelines, Final Report - Literature Review - Task 1”).

The literature review determined that, for pipelines abandoned in place, the issue of water conduits has been cited as a major concern from both environmental and economic standpoints for abandonment pipelines. However, no historical instances of water conduit formation in pipelines were found in the literature search. Water conduit formation appears to remain a theoretical, but likely concern for pipeline abandonment.

As proposed in the original scope of work, the most likely scenarios regarding the water conduit effect and its impacts were to be identified and assessed. Amec Foster Wheeler proposed that four theoretical scenarios be identified and discussed. These scenarios, identified in Section 6.1, are presented in more detail below.

8.0 THEORETICAL SCENARIOS

8.1 SCENARIO SELECTION

As proposed in the original scope of work, the most likely scenarios regarding the water conduit effect and its impacts were to be identified and assessed. Four general theoretical scenarios were identified in which the effects of water conduit formation within an abandoned pipeline right-of-way were considered to have higher possible environmental or safety consequences, should they occur.

1. Contaminated Sites,
2. Inclines,
3. Recharging Water Bodies (rivers, lakes, oceans), and
4. Small Water Bodies (wetlands, sloughs).

⁸ Pipeline Abandonment Steering Committee (PASC). Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues (1996). Website: <http://www.neb-one.gc.ca/prtcptn/pplnbndnmnt/pplnbndnmnttchnclnvrmmntl-eng.html>. Accessed June 21, 2016

These scenarios are described as follows.

1. Contaminated Sites

Water conduit formation occurs at contaminated sites in which the abandoned pipeline transects or is in the vicinity of historical or potential future contamination, including other active, abandoned or decommissioned pipelines.

2. Inclines

Abandoned pipelines left *in situ* on inclines are recognized as areas of increased possible risk for water conduit formation. Abandoned pipelines left *in situ* on inclines were recognized as areas of increased possible risk for water conduit formation

3. Recharging Water Body (rivers, lakes)

Recharging water bodies (i.e., large, surficial water bodies, or extensive shallow aquifers) in direct contact with an abandoned pipeline or pipeline Right-of-Way (ROW). The abandoned pipeline/ROW could transfer or displace water to or from the recharging water body depending on local or regional hydrogeological/hydrological conditions, but the natural hydrogeological/hydrological function of the large water body would not be impaired due to its size (e.g. volume or rate of recharge).

4. Small Water Body (wetlands, sloughs)

Small water bodies (i.e. small surficial water bodies, or local or perched shallow aquifers) in direct contact with an abandoned pipeline or pipeline ROW. The abandoned pipeline/ROW could transfer water to or from the small water body depending on local hydrogeological/hydrological conditions. The volume of water removed/added in comparison to the existing amount of water in the small water body could immediately and/or permanently impact or impair the natural function of the small water body due to its limited size.

9.0 METHODOLOGY

Theoretical scenarios of risks due to water conduit scenarios have been proposed, but an understanding of the requisite conditions for water conduit formation in real-life applications has yet to be adequately established. Understanding the prevalence and magnitude of risks of water conduit formation is a crucial aspect of pipeline abandonment.

Amec Foster Wheeler combined an evaluation of the risks identified within the literature review (Task 1) and professional judgement to expand key theoretical scenarios presented within previously reviewed material. Amec Foster Wheeler's and Decom's experience and judgement have been earned over years of work as both a consultant to, and client in the energy and pipeline sector, working in the geotechnical, environmental, and regulatory fields.

10.0 POTENTIAL MITIGATION MEASURES FOR WATER CONDUIT SCENARIOS

Mitigation and management measures applicable to the above scenarios are described below, and Table 1 “Management and Mitigation Options for Water Conduit Scenarios”. Depending on site specific conditions, not all measures will be appropriate for all scenarios at all times; however, all measures should address safety and environmental protection.

1. Segmentation (cut and capping, trench plugs)

Segmentation is the introduction of any measure within the abandoned pipeline to prevent fluid movement. Examples include cut and capping, earthen plugs, foam plugs, and/or section removal. The discussion would assume whatever method used would result in permanent cessation of water movement through the segmentation location.

2. Filling of Abandoned Pipeline with Inert Material

To avoid water conduit formation of an abandoned pipeline short sections of the line could be filled with an inert/non-reactive substance such as a bentonite slurry. Filling of the pipeline precludes its use as a conduit. This measure could be used in areas where pipeline removal activities are perceived as being too destructive to the local environment or existing infrastructure.

3. Removal of Conduit at the Specific Scenario Location

Sections of an abandoned pipeline can be removed, effectively breaking the conduit. This action assumes that backfill material used to fill the void left by the line’s removal is compacted to an equivalent degree as the surrounding native soils so as to avoid creating a permeable soil conduit in place of the pipeline. This measure denies water entry in to the line at a specific scenario location.

4. Removal of Conduit Downgradient of the Specific Scenario Location

Should pipeline removal at a specific scenario location be considered high risk due to infrastructure or environmental concerns, then sections of the abandoned pipeline located downgradient of the area of concern can be removed instead. This action also assumes that backfill material used to fill the void left by the downgradient line’s removal is compacted to an equivalent degree as the surrounding native soils. While this measure may allow water entry in to the line at the immediate and specific scenario location, it stops water transport further downgradient.

5. Hydrological and Hydrogeological (Surface Water) Features Management

Hydrological and hydrogeological (surface and near-surface water) feature management includes installation of surficial or subsurface features to permanently modify the prevailing surficial water or groundwater profile in order to reduce or eliminate the risk of water conduit formation. Feature management could include: surface contouring, installing geomembranes, drainage ditches, weeping tiles, and installing permanent or semi-permanent pumps, to passively or actively manage surface water or groundwater before or when it enters a pipeline.

6. Spill Management Protocols Including Remediation

Applicable to the Contaminated Sites Scenario, this measure relies on the use of existing spill/release protocols and clean-up technologies to remediate historical, current or future releases so that contamination is limited and is not spread further by the water conduit effect.

7. Monitoring

Monitoring activities can include using aerial photography, visual inspections, groundwater monitoring by observation well/piezometer network, or regularly scheduled overflights.

8. Placement of Drainage Points in an Abandoned Pipeline

Strategically locating drainage points within an abandoned pipeline could be done to permanently accommodate draining the pipeline to areas of lesser or no environmental impact.

9. Use of Topography, in Place of Segmentation to Provide Hydraulic Disconnection

Examination of using existing elevation profiles of a pipeline to assess the likelihood of water conduit formation and a discussion of limits of travel of the water in the line.

11.0 SCENARIO ANALYSIS

Each scenario will be described and discussed as follows:

- General description of the scenario.
- Assumptions specific to that scenario.
- Presentation of a figure(s) that illustrates a conceptual layout of the infrastructure and natural environment elements of the scenario.

- Discussion of the possible implications of water conduit formation for the specific scenario, including:
 - Considerations that should be understood and evaluated to select and implement appropriate mitigation,
 - Potential monitoring programs, and
 - Potential management/mitigation measures that may be employed for the specific scenario.

11.1 GENERAL ASSUMPTIONS FOR ALL SCENARIOS

While the specific conditions for water conduits to occur vary, some fundamental assumptions are shared in all scenarios. These are:

- 1) Given enough time and a growing inventory of abandoned pipelines, water conduits on some scale will occur in abandoned pipelines; however, without specific conditions being met (some of which are described in this report) these pipelines are not necessarily going to negatively affect the environment or nearby stakeholders.
- 2) Scenarios are general. Specific factors for any scenario may change, interact with and/or cancel out other factors or create new scenarios.
- 3) There is an engineered isolation of the abandoned pipeline from active facilities. In the event that the abandoned pipeline is cut, the exposed ends will be sealed such that the likelihood and consequences of water entering through exposed ends of the pipeline will be less than through perforations in the pipeline due to corrosion.
- 4) Pipeline corrosion is understood to initially occur gradually. Water would fill the pipeline until a new hydrostatic equilibrium is established through increasingly larger perforations in the pipeline wall. Catastrophic pipeline wall failure is not anticipated to occur.
- 5) The condition of the pipeline is not subjected to failure due to external forces (landslides, earthquakes, floods, high impact events, construction of nearby facilities, or contact with agricultural/utility/construction implements).
- 6) In any location where failure occurs, the risks associated with water conduits formation should be re-evaluated.
- 7) Over time, significant corrosion will result in the destruction of the pipe, leaving a void space that would likely be filled by subsiding overlying/adjacent soils. The abandoned pipeline trench backfill material could act/continue to act as a water conduit.
- 8) To facilitate the conditions for water conduits formation, a long term viewpoint (>100 years) needs to be considered. Given the correct conditions, it is recognized that with changes in the condition of pipeline walls and pipeline trenches water conduits theoretically will continue to occur indefinitely.

- 9) The pipeline is “clean” and doesn’t introduce contamination from products remaining within the abandoned pipeline. Any existing in-pipe concentrations of contaminants of potential concern are not in excess of regulated standards.
- 10) The corrosion of the pipeline and coatings will not be a source of significant concentrations of contaminants of concern.
- 11) The scenarios described herein would not be viable if the corroded and abandoned pipeline is below the groundwater table elevation, as it would be flooded (i.e., water, at any theoretical intake point created by corrosion, could not enter the line).

Mitigation and management options offered in the scenarios below are general in nature. Preferred options need to take into account that the abandoned pipeline trench backfill material, especially after extensive pipe corrosion, collapse and subsidence, could act as a water conduit, depending on backfill soil permeability and pipeline construction techniques (e.g., use of trench plugs).

11.2 SCENARIO 1 - CONTAMINATED SITES

Scenario Description:

An abandoned pipeline/ROW could transfer water from a contaminated site if the pipeline transects or is in the close vicinity to the contamination. Downgradient receptors would be at risk. (See Figures 1 and 2.) Contamination could be the result of historical or future impacts from a variety of sources including other active, abandoned or decommissioned pipelines.

Scenario Specific Assumptions:

- 1) This scenario applies to any form of contamination; however, given the likelihood that linear projects align for extended distances, a petroleum product release from another petroleum product pipeline, or pipeline related activity (e.g. construction), is considered the most likely source
- 2) Existing and future site management plans should have allowances for the management of product releases.
- 3) Existing surficial soil/water management should prevent or reduce the transmission of material into the corroded pipeline.

Discussion:

For the purposes of this discussion four contamination scenarios were identified: future releases, managed historical contamination, unmanaged historical contamination and external contamination. Each type has different mitigation considerations which are sufficiently diverse to be discussed separately.

Future contaminant releases are identified as possible risks for water conduit formation increasing the risks and effects of contamination given a spill or release in the future, in the vicinity of the abandoned pipeline.

Managed historical contamination is identified as contamination in which the properties, risks and probable effects are well understood. A managed contaminated site requires an understanding of the underlying hydrological and hydrogeological processes in the vicinity of the site, a model of likely future contaminant migration, the extent and concentrations of contaminants of concern and of the short and long term effects on affected stakeholders and the environment.

Unmanaged historical contamination sites include locations of known contamination in which the understanding of the conditions affecting stakeholders and the environment are incomplete.

External historical contamination involves contamination from a third (external) party, which crosses the pipeline right-of-way. This contamination has no relation to historical pipeline operations or product transfer. The history of the contamination, product type, and the site's hydrological processes may not be known to the abandoned pipeline owner or the party responsible for the historical release or its management/ mitigation.

Management/Mitigation Options:

Future Contaminant Release near an Abandoned Pipeline:

Contaminated sites management standards as of the early 2000s are such that in the event of a release impacted sites are highly regulated and are continuously managed. Companies also must actively manage existing known spills in a timely fashion, and extensively document remediation activities associated with all releases. Even with an immediate response, spill areas that are hydraulically connected to abandoned pipelines remain a risk for increased spreading of contamination through water conduit effects to down gradient receptors.

In the event of a future release adjacent to an abandoned pipeline, it is reasonable to assume that response plans developed to address existing contaminated sites will include adequate mitigation and management options to deal with potential transport of impacts within abandoned pipeline rights-of-way. If a future⁹ contaminated site is identified that is potentially hydraulically connected to an abandoned pipeline, mitigation measures should also be developed to address possible increased risks due to water conduits.

Should a future release occur adjacent to an abandoned pipeline, it should be assumed that the abandoned pipeline has been compromised (corroded) and will act as a conduit (i.e., released contaminants will enter and flow through the abandoned pipeline similar to how water would). It is anticipated that a focus of initial response efforts would be to ensure the released product and abandoned pipeline are hydraulically isolated. If hydraulic isolation cannot be established and maintained, removal or remediation of the abandoned pipeline should be considered a priority.

Proactive mitigation measures could include providing accurate mapping, and tying of abandoned pipeline infrastructure information (location, condition, elevation) to existing contaminated site management databases, maintaining signage of the pipeline along a right-of-way, understanding the local and regional hydrological and hydrogeological settings associated with the affected infrastructure, and providing responding personnel and stakeholders timely information to better assess and contend with increased risks of spreading contamination through abandoned infrastructure.

In the event of contamination of a corroded pipeline from a future external source, contamination could be spread by the water conduit effect; therefore, the contaminant source needs to be isolated, removed or remediated and the pipeline cleaned (e.g. flushed and or purged, assuming the pipeline is not significantly corroded). It is possible that segmentation and removal of the contaminated sections of the line may be required to fulfill clean-up requirements.

Managed historical contamination: Managed contaminated sites are understood to be in the process of being remediated and (similar to future contamination) a proactive approach allowing site managers to consider the risks is considered the best mitigation. Companies should ensure managed contaminated sites consider the possibility of abandoned pipelines and associated water conduit effects in their management plan. Given the condition of the abandoned pipeline, the plan should consider the likelihood that the pipeline has corroded sufficiently to be a water conduit and also if the trench may preferentially conduct contaminants. In any case, the authors suggest that stakeholders should be well informed of the increased risks and act accordingly.

The suite of applicable tools, which may be considered to mitigate or manage this scenario, could include changing the timeline for remediation of surrounding materials, cleaning/remediating contaminated media, mounding, roaching, installing geomembrane, water diversion, groundwater pumping, pipeline removal, or segmentation.

Unmanaged historical contamination: Unmanaged contaminated sites should be clearly identified at the time of abandonment to regulators. The pipeline company should be made responsible for understanding unmanaged contaminated sites and bringing them in-line with managed contaminated sites before corrosion of the pipeline is anticipated.

External historical contamination: Historical contamination from external parties should be addressed similarly to the managed/unmanaged sites. The responsibility of the abandonee (a pipeline company, owner, manager, or controlling entity of the abandoned pipeline) should be to ensure that the implications and possible costs for additional mitigation associated with the affected abandoned infrastructure are identified to all stakeholders, and concerns about the water conduit effect, be identified to the external party.

⁹ Existing management plans for older pipelines may not have incorporated enough local hydrogeological information to assess if the water conduit effect is an issue.

At the time of abandonment, the pipeline company should make efforts to identify sites where contamination created by others exists, and ensure external parties are sufficiently sophisticated to manage the contamination, or ensure that the contamination remains hydraulically separate from the abandoned pipeline.

11.3 SCENARIO 2 – INCLINES

While no studies concerning abandoned pipelines were identified in the course of the literature review, the risk of water entering an abandoned pipeline in a sloped area was raised in the 1996 Discussion Paper, the 2007 CEPA Paper and the 2010 DNV report.

Scenario Description:

Localized inclines are defined by an average grade sufficiently steep enough for water and material entering the evacuated pipeline at or near the top of this inclined zone to make its way to the bottom of the slope (i.e., friction is overcome, allowing for the movement of material down the incline). (See Figure 3.) This condition is likely to occur where the pipeline has corroded sufficiently to prevent continuous fluid movement.

Water bodies, such as streams, rivers and lakes located at the bottom of a slope could face an increased risk of eroded material transport entering them and negatively affecting the existing ecosystem. There is also a possibility of water in the pipeline being able to continuously transport material away from any one ingress point resulting in a sinkhole. Other identified risks include: higher erosion levels at the ingress and egress points from the pipeline and possible flooding in low lying areas near to the pipeline.

The risks would be increased proportional to the potential energy of the system. Elements which could increase the risks include: greater differences in elevation, steeper slopes (inclines), the size and nature of materials being transported and the location of higher risk receptors. Variations in the incline, elevation and condition of the pipeline, could positively or negatively increase the risk depending on site conditions.

Scenario Specific Assumptions:

- 1) Steeper slopes mean a higher energy regime, resulting in increased water velocity and thus greater potential erosion at the pipe outlet point(s).
- 2) For longer and more gentle slopes, there is a greater likelihood of water flow being stopped (or slowed) by changes in topography.
- 3) There is a greater likelihood of entrapped material stopping within the pipeline and accumulating over time (i.e., a blockage is formed) on long, shallow inclines.
- 4) Existing surficial soil/water feature management (e.g. diversion berms) should prevent or reduce the transmission of material into the corroded pipeline.

- 5) Assuming that no, or poor, surface and near-surface water (Hydrological and Hydrogeological) feature management exists, it is anticipated that the natural areal extent of the zone of influence (possible collection zone of surface water from precipitation that could flow into the pipeline ROW) is limited to less than 10's of metres, from the pipeline ROW) and consequently low volumes of water/material would flow into the pipeline.
- 6) Nature of the receiving environment at the toe of the slope is sensitive to water discharge/erosion.
- 7) Presence of existing trench breaks/plugs.

Discussion:

Under the above conditions, it is possible the channeling of water into the pipeline or pipeline trench could result in erosion of surrounding soils and their transportation towards the downstream end of the inclined pipe. Release of this material from the abandoned pipe into a nearby surficial water resource or groundwater resource located at a lower elevation, could contribute to increased water turbidity, altered flow conditions or parameters (e.g., volume, temperature, groundwater chemistry), and erosion.

Erosion of material at ingress points could result in sinkhole formation, and erosion at egress points in flooding or material deposition. Also, erosion of sections of the slope by material transport by the water conduit effect could compromise slope stability, creating a geohazard condition that could lead to catastrophic slope failure.

It is anticipated that lower slope angles would result in lower energy regimes and therefore a lessening of the water conduit effect.

Management/Mitigation Options:

A key management option for this scenario is to deny water entry into the abandoned pipeline. The management of surficial water flow or channeling in this scenario should be similar to that of active pipelines. Surficial water channeling to buried pipelines within rights of way is well established within the industry.¹⁰ Pipeline companies are under strict conditions when constructing on steep slopes and regularly monitor and maintain those sections of pipelines for disproportionate slope movement or erosion.

Appropriate mitigation for this form of channeling primarily comprises surficial feature management (e.g., control berms, water bars, ground contouring, matting, vegetation planting, terracing) and subsurface constructed features within the trench (e.g., trench breakers/plugs/blocks). These techniques are well established in the pipeline construction and maintenance industries and the principles and methods should be applicable to pipeline abandonment. Additionally, water discharge points could be created along inclined areas to drain water from the slope and/or the pipe so that and erosion and flooding at the pipe outlet point at the bottom of the slope is reduced. If drainage along the incline is a factor, then it is imperative that the water be channeled in such a way to prevent re-entry into the trench or pipeline.

Management of erosion is an ongoing concern for active pipelines and could be a concern for abandoned lines as well. Wherever possible, determination of high erosion areas should be made.

The location and integrity of trench breakers and trench plugs along the abandoned pipeline should to be evaluated for long-term efficacy as, given sufficient time, the void space introduced by the corroded abandoned pipeline may compromise their ability to prevent water flowing down the trench. Where trench breakers/plugs have been used, creation of a pipeline isolation point (e.g. cutting and capping) may need to be considered.

Removal of the pipe on longer or steep slopes may be considered as an option but a variety of factors such as cost, safety, and slope stability need to be assessed and are likely to outweigh a the benefits of an inspection and surficial management strategy.

11.4 SCENARIO 3 – RECHARGING WATER BODIES

Scenario Description:

An abandoned pipeline/ROW could transfer water from a recharging water body depending on local or regional hydrogeological/hydrological conditions. (See Figure 4.) However, the natural hydrogeological/hydrological function of the large water body would not be impaired due to its size (e.g., volume and/or rate of recharge).

Scenario Specific Assumptions:

- 1) The recharging water body is of sufficient size (volume or recharge rate) that it cannot be drained by the water conduit effect. That is, losses to the abandoned pipeline (drainage) are equaled or exceeded by recharge to the water body; i.e., water balance for the water body is not measurably affected by water loss or gain due to water conduit effect.
- 2) Water loss from the recharging water body is at a rate that does not adversely affect other environmental receptors or water users dependent on that large water body.
- 3) Weathering (erosion) at the ingress or egress point are not eroding or transporting additional material (
- 4) Water from the recharging waterbody would be transported via the conduit effect to the next adjoining downgradient topographically created or engineered isolation point.

Discussion:

Recharging water bodies (i.e., large, surficial water bodies, rivers ¹¹ or extensive shallow aquifers) that are in direct contact with an abandoned pipeline or pipeline ROW could continuously lose water through the water conduit effect to a downgradient area.

¹⁰ A full discussion can be found within Pipeline Associated Watercourse Crossings, fourth edition. Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association and Canadian Gas Association. 2012. Pipeline Associated Watercourse Crossings. Prepared by TERA Environmental Consultants. Calgary, AB.

¹¹ In the case where there is a steep slope adjacent to a river it could be that a combination of water conduit effects should be considered.

The concern in this scenario is not that the recharging water body is affected but that the abandoned pipeline acts as a conduit and transports water, and possibly other material such as sediment or biota, to a different locale, damaging the receiving environment (e.g., by flooding agricultural lands), potentially acting as an intra-basin diversion. Thus, the recharging water body would continuously lose water (but due to recharge it would be replenished) and the adjacent area would continuously gain water.

Depending on local/regional hydrological/hydrogeological conditions, it is theoretically possible, though unlikely, that water movement from the recharging water body could become an ongoing continuous flow through the pipeline to an adjacent lower elevation area. This condition is considered unlikely as recharging water bodies generally exist at the lowest point of a hydrological systems (the bottom of valleys or slopes). Water would be more likely to travel to a recharge zone then away from one.

Should the pipe that drains a large recharging water body not have a discharge point, then a 'static equilibrium condition' would be reached once the abandoned pipe is filled with water from the recharging water body. Should the volume of water coming in to the pipe from the recharging water body equal the water volume leaving the pipe (at some discharge point), a 'dynamic equilibrium condition' could theoretically be reached. In the former case there are no further effects on the large water body other than the loss of some finite volume of water, now held in the previously voided pipe. In the latter case, transportation of water and material is possible on an ongoing basis.

Management/Mitigation Options:

As with previous scenarios, a key management option is to deny water entry into the abandoned pipeline. However, surficial water management measures conducted on a large, recharging water body may not be effective or cost efficient. Also, they could negatively impact natural processes operating within that water body. Removal of the pipeline could, in the short term, have a substantial impact on the water body, but may, over the longer term, be a reasonable option.

Furthermore, in the case of pipeline removal, soils in the former pipeline trench would require a high degree of compaction and/or trench breaks to prevent water conduit formation.

Other possible mitigation measures include capping the pipe where it intersects the water body, or filling the pipeline with a durable, inert substance to permanently plug the pipeline. The entire void space of the pipe would require filling within the length of pipe that intersects the large recharging water body and the zone of subsurface flow associated with the water body.

To avoid impacts to the large water body, engineered isolation or removal of the conduit on the downgradient side of the water body should be considered.

Creation of water discharge points (to drain water from the pipe) downgradient of the large water body is discouraged as this could create a continuous flow condition.

Any proposed pipeline abandonment project may require an assessment of associated large recharging water bodies prior to abandonment so that the water conduit effect is not realized.

11.5 SCENARIO 4 – SMALL WATER BODIES

Scenario Description:

An abandoned pipeline/ROW could transfer water from a small water body (i.e., small surficial water bodies, such as a permanent or ephemeral lake, stream, swamp, fen, or local or perched shallow aquifer) depending on local or regional hydrogeological/hydrological conditions. (See Figure 5.) The natural hydrogeological/hydrological function of the small water body could be temporarily or permanently impaired due to its limited size and sensitivity to water volume loss.

Scenario Specific Assumptions:

- 5) The small water body is of insufficient size (volume or recharge rate) for it to sustain water loss or gain without significant impact; i.e., water balance for the water body is measurably affected by water loss or gain due to water conduit effect.
- 6) Water loss from the small water body is at a rate that adversely affects other environmental receptors or water users dependent on that small water body.
- 7) This scenario is limited to considering risks associated with the loss of water for the small water body. It is possible that other issues including erosion or bank stability issues could also be associated with small water bodies, however the discussion of those issues in other scenarios is considered adequate.

Discussion:

In the event that corrosion of an abandoned pipeline permits drainage, a small water body could either temporarily or permanently experience loss of a volume of water sufficient to cause a detrimental environmental effect. The water body itself, related receptors, or water users could be affected.

A simple example of this scenario would be that of an ephemeral wetland with a localized low water table. Corrosion of the piping in an abandoned pipeline adjacent to the wetland could theoretically lead to partial or complete drainage of the wetland through the pipe. Water could sit contained in the pipe or drain out at some downgradient exit point.

Monitoring for the presence of small water bodies that could be affected by water conduit formation is complicated by their relatively small size, potentially complex hydrological relationships, and for many small wetlands, their ephemeral nature. The gradual disappearance of small water bodies in the vicinity of abandoned pipelines could indicate water conduit formation or be associated with periods of low precipitation. Multiple year monitoring may be required to understand pre-existing wetlands under these conditions.

Management/Mitigation Options:

Appropriate mitigation measures for small water bodies are potentially the most difficult to prescribe. As with previous Recharging Water Bodies scenario a key management option is to deny water entry into the abandoned pipeline. Although surficial water management measures are likely less costly to conduct on smaller water bodies as opposed to larger recharging water bodies, they may not be appropriate, as they could more easily negatively impact natural processes operating on a small water body. Removal of the pipeline could, in the short term, have a substantial impact on a small or ephemeral water body as is more likely to destroy the wetland than to protect it.

Other possible mitigation measures include capping the pipe where it intersects the small water body, or filling the pipeline with a durable, inert substance to permanently plug the pipeline within the hydrologically connected zone. To permanently prevent future water movement, the entire void space of the abandoned pipe would require filling in the area where the pipe intersects the small water body and its associated hydrological/hydrogeological zone of influence.

Any proposed pipeline abandonment project should consider an assessment of associated small water bodies prior to abandonment. This assessment should consider: the conditions found in the wetlands, the likelihood of successful reclamation of the water body, and presence of any species at risk or higher value considerations within small water bodies. In the case of small water bodies, this assessment is complicated by the fact that many small water bodies, especially wetlands, may belong to a regional wetland system with complex interrelationships between small lakes, wetlands and water tables. Monitoring necessary to determine losses due to the water conduit effect (as opposed to other causes) could be expensive, time consuming and potentially have appreciable uncertainty associated with the results.

Some regulatory bodies allow for replacement of wetlands in alternative protected locations as possible alternatives to restoring wetlands that have been lost due to construction. Where available, this option may be an alternative to monitoring/managing smaller water bodies such as wetlands over the longer term.

To avoid impacts to the small water body, engineered isolation or removal of the conduit on the downgradient side of the water body should be considered.

There are a potentially large number of small water bodies that could be intercepted by any abandoned pipeline (assuming a Canadian Prairie setting) with each water body having similar chances for water conduit formation, and requiring similar mitigation measures. Pipeline abandonment projects should consider the aggregate effect on all small water bodies in a given area (e.g. basin, wetland complex, or hydraulically connected system) and not be limited to any one water body.

12.0 CONCLUSIONS

Based on information obtained through the literature search, and based on our experience and known hydrological processes, we provide the following Table (Management and Mitigation Options for Water Conduit Scenarios) presenting management and mitigation options appropriate to each scenario, below.

While several theoretical water conduit scenarios have been established, an understanding of the requisite conditions for water conduit formation in real-life applications has yet to be adequately established. What is noteworthy is the lack of any record which specifically identified water conduits as having occurred. The lack of records may be because:

- the phenomenon is being mitigated by current industry practices while not specifically being cited in the records reviewed;
- the phenomenon is not being specifically monitored for in abandoned pipelines,
- the aggregate retired infrastructure within the pipeline industry has not sufficiently deteriorated for the water conduits to occur, or
- the conditions for water conduits to form are simply unable to occur in nature.

When looking at abandonment projects, both regulators and industry are interested in ensuring appropriate liabilities are being identified. Amec Foster Wheeler notes that, given the predicted corrosion of pipelines may take decades to manifest, there is considerable time to develop a more complete understanding of water conduits before implementing mitigation.

Some studies have taken the approach that the risks should be addressed at the time of abandonment (i.e. mitigation and management practices are carried out at that time), it may also be appropriate to assign a liability based on best mitigation practices (like those in the attached Table) but not implement the mitigations until a better understanding of water conduits formation is acquired.

In an abandonment project, possible mitigation measures should be assessed against their potential safety and environmental consequences. As part of an abandoned pipeline monitoring/management program, monitoring at suspected water conduit formation locations, as described in the theoretical scenarios, should be conducted.

In addition to new abandonment projects, Amec Foster Wheeler looks forward to incorporating the results of additional research on historically abandoned pipelines including upcoming work to be completed as part of PARSC research initiatives. If the results of this work reveals the presence of water conduits, study of the requisite conditions should be completed and appended as an update to this report.

13.0 CLOSURE

This report has been prepared for the exclusive use of the Petroleum Technology Alliance Canada (PTAC) and authorized users for specific application to this project. The work was conducted in accordance with the Agreement executed between PTAC and Amec Foster Wheeler Environment & Infrastructure, the agreed scope of work approved verbally and in writing by PTAC, and generally accepted practices. No other warranty, expressed or implied, is made.

Should you have any questions regarding this report, please call David Parbery at (780) 377-3581.

Yours truly,

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Permit to Practice No. P-04546



David Parbery, M.N.R.M., P. Geo.
Senior Environmental Geoscientist

Andrew Hoskins, B.Sc., P. Geo.
Director, Decom Consulting Ltd.

Reviewed by:

Gary Beckstead, P.Eng.
Principal Engineer – Water Resources

Table: Management and Mitigation Options for Water Conduit Scenarios

Management / Mitigation Options	Pipeline Modifications - Denies Water Entry Into APL*				Manages Water Flows To, Through and Around APL				
	Cutting & Capping of APL	Filling of APL with Inert Material	Removal of Conduit (APL) at the Specific Scenario Location	Removal of Conduit (APL) Downgradient of Specific Scenario Location	Surface Water Features Mgt. Measures	Use of Existing Spill Mgt. Protocols, incl. Remediation	Monitoring	Use of Drainage Points	Evaluation of Hydraulic Disconnection By Elevation Change
Scenario									
1 - CONTAMINATED SITES	✓	--	✓	--	✓	✓	✓	✓	✓
2 – INCLINES	✓	--	✓	--	✓	--	✓	--	--
3 – RECHARGING WATER BODIES	✓	--	--	✓	--	--	✓	--	✓
4 – SMALL WATER BODIES	--	✓	--	✓	✓	--	✓	✓	✓

* - APL - Abandoned Pipeline
 -- likely not applicable
 ✓ - applicable

References:

Amec Foster Wheeler Environment & Infrastructure. 2016. PTAC - Petroleum Technology Alliance Canada, PARSC 012 – Water Conduit Effect in Abandoned Pipelines, June 2016 Task 1 – Update report. 27pp.

Canadian Energy Pipeline Association. 2007. Pipeline Abandonment Assumptions: Technical and Environmental Considerations for Development of Pipeline Abandonment Strategies. Prepared for the Terminal Negative Salvage Force of the Canadian Energy Pipeline Association. 85 pp.

Det Norske Veritas. 2010. Pipeline Abandonment Scoping Study. Prepared for the National Energy Board, Report No. EP028844. 85 pp.

Pipeline Abandonment Steering Committee (PASC). 1996. Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues. 16 pp. Website: <http://www.neb-one.gc.ca/prtcptn/pplnbndnmnt/pplnbndnmnttchnclnvrnmntl-eng.html>.

Pipeline Associated Watercourse Crossings, fourth edition. Canadian Association of Petroleum Producers, Canadian Energy Pipeline Association and Canadian Gas Association. 2012. Pipeline Associated Watercourse Crossings. Prepared by TERA Environmental Consultants. Calgary, AB.

APPENDIX A

**Pipeline Abandonment Research Steering Committee (PARSC):
Request for Proposal PARSC 012 – Water Conduit Effects in Abandoned Pipelines**



Request for Proposals

PARSC 012 –Water Conduit Effect in Abandoned Pipelines

Date: March 21, 2016

Purpose

On behalf of the Pipeline Abandonment Research Steering Committee (PARSC), PTAC wishes to retain the services of a research organization or consulting firm (the Contractor) to provide the services described in this document. Interested parties are invited to submit full proposals according to the specification provided herein.

Background

Pipeline abandonment¹ refers to the permanent removal from service of a pipeline. Depending on a number of factors, sections of pipeline may be abandoned in place or removed. When abandoned in place, potential risks exist for the abandoned pipe to act as a water conduit able to intercept and channel drainage along the right-of-way, potentially at greater rates than natural drainage patterns. The abandoned pipeline may also become a conduit for transportation of contaminants from any sources to other points along the pipeline.

Project Objective

The objective of this project is to review the state of knowledge and provide guidance concerning the water conduit effect and its potential impact for abandoned pipelines.

Project Scope

This project will involve a literature review and a paper study by a recognized expert of the water conduit effect and of its potential environmental impact in abandoned pipelines. Potential environmental impact scenarios and mitigation measures such as segmentation will also be reviewed. It is not expected that laboratory work will be required.

Reporting and Payment Milestones

The Contractor will provide short monthly status reports and will be available to teleconference with PARSC during its meetings, which are generally held every 6 weeks. The applicant will also propose major project milestones when the Contractor will provide a progress report about deliverables and PTAC will make progress payments.

¹ In the context of the present technical topic, pipeline abandonment and pipeline decommissioning are considered similar as they both imply permanent removal from service.



Deliverables

1. Literature review and analysis
2. Status and progress reviews with PARSC (short progress report generally every 6 weeks)
3. Draft reports at each project milestone
4. Final report and presentation to PARSC

Budget

The applicant will indicate the cash budget and any other resources required to complete the project.

Confidentiality

The Contractor will be required to sign a confidentiality agreement related to the project. Disclosure of any project information will be at the discretion of PARSC. It is the intention of PARSC that key results and outcomes will eventually be made public.

Intellectual Property

All intellectual property rights and publication rights for the deliverables and reports produced by the Contractor in this project (but not including Contractor models and tools) will be the property of the funding organizations in PARSC.

RFP Schedule

March 24, 2016	RFP issued
April 14, 2016	Deadline for receipt of full proposals by PTAC
April 22, 2016	Invitation to a short list of applicants to present and discuss their full proposal with PARSC
April 28, 2016	Meeting of shortlisted applicants with PARSC
May 13, 2016	Selection of the best value proposal by PARSC

Contents of Full Proposals

The requested full proposal should contain a detailed project description, budget and schedule which would be used as the basis of a contract. A 5 to 10 page document addressing the following elements must be delivered electronically or by mail to PTAC by the deadline stated above:

- Scope of work
- Methodology
- Deliverables



- Schedule
- Personnel assigned to the project
- Qualifications
- Budget and costs, including information on breakdown by major scope element and allocation of personnel and applicable rates
- Milestone payment information

The page count does not include any attachment such as CVs, company description or literature references that the applicant may wish to include.

Contact Information

Katie Blanchett
PTAC
Suite 400,
500 Fifth Avenue S.W.
Calgary, Alberta T2P 3L5
Tel.: 403-218-7714
Email: kblanchett@ptac.org

For Technical Inquiries

Marc Godin
Tel.: 403-870-5402
Email: marc.godin@portfire.com



Attachment 1 - PARSC Program Background

Pipeline abandonment refers to the permanent removal from service of a pipeline. Depending on a number of factors, sections of pipeline may be abandoned in place or removed.

CEPA, the National Energy Board (NEB), the Alberta Energy and Utilities Board (AEUB) and the Canadian Association of Petroleum Producers (CAPP) have collaborated on technical and environmental issues associated with pipeline abandonment, which issues were discussed in the documents referenced below. In 1996, the NEB published a review document titled "[Pipeline Abandonment – A Discussion Paper on Technical and Environmental Issues](#)". In 2007, CEPA published a report titled "[Pipeline Abandonment Assumptions](#)" which discussed technical and environmental considerations for development of pipeline abandonment strategies. A comprehensive review was undertaken by the NEB as part of the Land Matters Consultation Initiative (LMCI) which involved four discussion papers on the different topic areas, 45 meetings and workshops in 25 communities across Canada, and written submissions from 13 parties. The [final LMCI report](#)², published in 2009 recommended that knowledge gaps on the physical issues of pipeline abandonment be addressed. Thus, Det Norske Veritas (DNV) was commissioned to conduct a literature review regarding the current understanding worldwide with respect to the physical and 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. DNV published this [Scoping Study](#) in November 2010.

CEPA and PTAC have established the Pipeline Abandonment Research Steering Committee (PARSC) as a framework for collaboration to guide and direct innovation and applied research, technology development, demonstration, and deployment in order to address knowledge gaps summarized in the DNV Scoping Study.

Research findings from the PARSC projects will be shared on a broad scale throughout the pipeline industry, the oil and gas industry, as well as with regulators, government agencies, and other stakeholders.

² Online at http://publications.gc.ca/collections/collection_2010/one-neb/NE23-152-2009-eng.pdf

APPENDIX B

Reviewed Sources

	Type/Source	Act/Regulation/Guideline	Source	Content related to water conduits	Comments
	CANADA Federal				
1	Regulation - National Energy Board	National Energy Board Act	http://laws-lois.justice.gc.ca/eng/acts/N-7/index.html	No relevant content	
2	Regulation - National Energy Board	NEB Onshore Pipeline Regulations, 1999	http://laws-lois.justice.gc.ca/eng/regulations/SOR-99-294/	50. A company shall include in an application made under section 74 of the Act for leave to abandon a pipeline or part of one the reasons, and the procedures that are to be used, for the abandonment.	Must provide reasons for actions associated with abandonment.
3	Regulation - Canada Federal	Canada Oil and Gas Operations Act	http://laws-lois.justice.gc.ca/eng/acts/o-7/	No relevant content	
4	Standards - Canadian Standards Association (CSA)	CSA standard Z662-11 Oil and gas pipeline systems. January 2012.	Accessed on internal AMEC IHS system.	10.16 Abandonment of Piping 10.16.1 The decision to abandon a section of piping, in place or through removal, shall be made on the basis of an assessment that includes consideration of current and future land use and the potential for safety hazards and environmental damage to be created by ground subsidence, soil contamination, groundwater contamination, erosion, and the creation of water conduits . 10.16.2 Piping that is abandoned in place shall be (a) emptied of service fluids; (b) purged or appropriately cleaned or both; (c) physically separated from any in-service piping; and (d) capped, plugged, or otherwise effectively sealed .	
5	Standards - Canadian Standards Association (CSA)	CSA Standard Z662-13. Oil and gas pipeline systems (DRAFT)	http://www.rds.ontarioenergyboard.ca/webdrawer/webdrawer.dll/webdrawer/rec/468147/view/.	10.16.1 The decision to abandon a section of a pipeline, whether in place or through removal, shall be made on the basis of a documented abandonment plan that includes the rationale for the abandonment, consideration of regulatory requirements, landowner consultation, effect on terrain and water, road and railway crossings, as well as current and potential land use. The plan shall consider the potential for safety hazards and environmental damage that could be created by ground subsidence, soil admixing or contamination, groundwater contamination, erosion, and the creation of water conduits. Note: Pipeline Abandonment: A Discussion Paper on Technical and Environmental Issues, National Energy Board, November 1996, Section 2 provides guidance. 10.16.2 Buried pipelines A buried pipeline that is abandoned in place shall be (a) emptied of service fluids; (b) purged or appropriately cleaned or both in a manner that leaves no mobile materials remaining in the pipeline; (c) physically separated from any in-service piping; (d) capped, plugged, or otherwise effectively sealed; (e) cut off at pipeline depth; . (f) left without any internal pressure;	
6	Guidelines - National Energy Board	National Energy Board (2011) Regulating Pipeline Abandonment	https://www.neb-one.gc.ca/prtcptn/pplnbndnmnt/rgltn/gpplnbndnmnt-eng.pdf	Abandonment Plans Table of Contents Example: 5. Estimation of risk and risk reduction plans a. Contamination removal or management b. Soil subsidence c. Corrosion effects d. Pipe collapse e. Soil erosion effects f. Water conduit g. Water crossings h. Transportation and utility crossings	
7	Guidelines - National Energy Board	National Energy Board Filing Manual (2015 update)	https://www.neb-one.gc.ca/bts/ctrg/gnmb/flngmnl/flngmnl-eng.pdf	Guide K Filing Requirements for Engineering (Abandonment) Provide details to confirm that the pipeline is going to be: • emptied of service fluids; • purged or appropriately cleaned or both in a manner that leaves no mobile materials remaining in the pipeline; • physically separated from any in-service piping; • capped, plugged, or otherwise effectively sealed; • left without any internal pressure; • left in a state where road, railway or utility crossings are not at risk of disturbance due to settlement; • equipped with signage; and • monitored as appropriate for subsidence and to maintain adequate cover for existing and future land use.	
8	Guidelines - National Energy Board	National Energy Board (2011) Remediation Process Guide	https://www.neb-one.gc.ca/sftnvrnmnt/nvrnmnt/rmdtn/prcssgd/rmdtnprcssgd-eng.pdf	SELF ASSESSMENT - NEED FOR A REMEDIAL ACTION PLAN Question 12. Is there a potential for contamination to reach surface water based on distance to a waterbody, ditches, soil permeability, conduits etc.? Question 15. Are there any utility conduits through or under the spill site that will remain in contact with any contaminant?	
9	Guidance - Canadian Association of Petroleum Producers	CAPP Environmental operating Practices for the Upstream Petroleum Industry Saskatchewan – Pipelines. April 2002	http://www.capp.ca/publications-and-statistics/publications/40065	No referenced content to water conduits.	

10	Guidance - National Energy Board	CAPP - Pipeline Abandonment, A Discussion Paper on Technical and Environmental Issues, November 1996	http://publications.gc.ca/site/eng/65402/publication.html	<p>3.9 Creation of Water Conduits</p> <p>Plugs should be installed at appropriate spacings to ensure that changes in surface and ground water conditions will not result in water flow through the pipeline. When identifying locations for the plugs, consideration should be given to pipeline access during the placement of the plugs and the resulting effects of the ground disturbance. Where the pipeline crosses a wet area, a plug should be placed just downstream of the wet area, to prevent its drainage, and also at an appropriate location upstream of the wet area, to prevent the wet area contamination by water flowing along the pipeline. The plugs should be long enough so that corrosion downstream of the plug will not result in water entering the pipe.</p> <p>On slopes, water could seep into the pipeline through perforations and exit at unacceptable locations such as agricultural areas or areas where excessive erosion would result. The water should be allowed to exit at frequent intervals and at preferred locations in order to minimize potential impacts from the flow of water and the disruption to natural drainage patterns. Typical locations for plugs are provided in the following table.</p> <table border="1" data-bbox="1066 624 2191 937"> <thead> <tr> <th colspan="2">Table 3-1 Recommended Plug Locations</th> </tr> <tr> <th>Terrain Feature</th> <th>Plug Locations</th> </tr> </thead> <tbody> <tr> <td>waterbodies/watercourses</td> <td>above top of bank</td> </tr> <tr> <td>long inclines (>200m), river banks</td> <td>at top and bottom of slope and at mid-slope for long inclines</td> </tr> <tr> <td>flood plains</td> <td>at boundaries</td> </tr> <tr> <td>sensitive land uses (e.g. natural areas, parks)</td> <td>at boundaries</td> </tr> <tr> <td>near waterfalls, shallow aquifers, groundwater discharge and recharge zones, marshes, sloughs, peatlands, highwater table areas</td> <td>at boundaries and should include an adequate buffer zone</td> </tr> <tr> <td>cultural features (population centres)</td> <td>at boundaries</td> </tr> </tbody> </table> <p>The plugs should adhere to the pipe, be impermeable and non-shrinking, and able to resist deterioration. Examples of suitable materials are concrete grout or polyurethane foam. The use of impermeable earthen plugs may also be a viable option.</p> <p>In the case of pipeline removal, water pathways through the uncompacted pipeline trench material must be prevented or interrupted. The principles governing the locations of trench breakers are the same as those governing the locations of plugs for pipelines abandoned in place.</p>	Table 3-1 Recommended Plug Locations		Terrain Feature	Plug Locations	waterbodies/watercourses	above top of bank	long inclines (>200m), river banks	at top and bottom of slope and at mid-slope for long inclines	flood plains	at boundaries	sensitive land uses (e.g. natural areas, parks)	at boundaries	near waterfalls, shallow aquifers, groundwater discharge and recharge zones, marshes, sloughs, peatlands, highwater table areas	at boundaries and should include an adequate buffer zone	cultural features (population centres)	at boundaries	
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11	Guidance - Canadian Energy Pipeline Association	CEPA Pipeline Abandonment Assumptions – Technical and Environmental Considerations for Development of Pipeline Abandonment Strategies, September 2006 – April 2007	https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90463/501473/501488/501198/515103/A1F2Z4-TNS_Tech_Guidelines_on_Abandonment_(r12)_April_10_07_JKK.pdf?nodeid=515104&vernum=0&redirect=3	The potential for a pipe abandoned in place to become a conduit for water movement was discussed in the 1996 Discussion Paper. In developing the pipeline abandonment matrix, it is assumed that the abandoned pipe would be segmented at appropriate locations to address this potential concern. In determining the appropriate locations for the segmentation, factors such as terrain and land use are considerations. The 1996 Discussion Paper provides specific locations where segmentation and plugs are recommended (Table 3-1 of that report) and these remain valid today. Impermeable materials such as concrete, polyurethane foam or soil are still reasonable materials to create plugs in the pipe.																	
12	Guidance - National Energy Board	Pipeline Abandonment Legal Working Group- Legal Issues Relating to Pipeline Abandonment: A Discussion Paper	https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90463/501473/501196/501199/504177/542924/C-1-13F_Appendix_D_PASC_Legal_Issues_Paper_%28A112C8%29.pdf?nodeid=543363&vernum=-2	No relevant content																	

13	Guidance - National Energy Board	Det Norske Veritas, Pipeline Abandonment Scoping Study, NEB. Nov. 2010	https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90463/782060/782061/795792/804521/850212/8-5-13-Attachment_11-Pipeline_Abandonment_Scoping_Study_-_A2Y0S9_.pdf?nodeid=850222&vernum=0	<p>4. Environmental Issues</p> <p>b) Soil resources Where pipe is to be removed, the erosion issues will be similar to those associated with installation.</p> <p>Abandonment in-place can lead to erosion in two ways. Corrosion perforated pipe can conduct water along the right-of-way to exit the pipeline in new locations. Later, as the pipeline collapses, resultant soil subsidence can create water conduits able to intercept and channel drainage along the right-of-way, potentially, at much greater velocities than natural drainage patterns would allow. To examine ground subsidence risks for abandoned pipelines the Pipeline Abandonment Steering Committee commissioned both a geotechnical study and a survey of pipeline companies. Neither the industry survey nor follow-up discussions identified any instances of observed subsidence.</p> <p>However, the Committee recommended that a field observation program be put into place that would allow tolerance criteria to be developed. This remains to be done.</p> <p>c) Creation of water conduits</p> <p>The potential for pipelines to create water conduits as a result of abandonment creates risks of unnatural drainage and unwanted transport of materials that can include eroded soils and contaminants. Some potential exists for water movement in un-compacted, back-filled trench material that may remain after the pipe has been removed. However, the greatest concern relates to pipelines abandoned in place.</p> <p>The 1996 Discussion Paper identifies measures such as pipeline plugs and trench breakers for managing the risk of undue water mobility. The material suggests that this issue is understood and manageable.</p> <p>5.1.4 Conduit Effect</p> <p>No examples of an abandoned pipeline acting as a conduit for water movement were found in the literature review. The potential for a pipe abandoned in place to become a conduit for water movement was discussed in Section 3.9 of the PADP 1996. If the abandoned pipeline is clean, the potential environmental risks could be related to draining wetlands or, conversely, flooding inappropriate land areas or to transport soil material inside the pipe to a down slope location where it may escape and cause impacts. If the pipe is not clean there may be a risk of transporting contaminants.</p> <p>In order to address these potential issues, it is assumed that the abandoned pipe would be segmented at appropriate locations. Both the CAPP 2002 Guidelines document and the CEPA 2007 Pipeline Abandonment Assumptions document refer to Table 3-1 of the PADP 1996 for determining the appropriate locations where segmentation and plugs are recommended which remain valid today. Impermeable materials such as concrete, polyurethane foam or soil are still reasonable materials to create plugs in the pipe.</p> <p>In the case of pipeline removal, water pathways through the uncompacted pipeline trench material must be prevented or interrupted. The principles governing the locations of trench breakers are the same as those governing the locations of plugs for pipelines abandoned in place. The occurrence of the conduit effect on the outside of an abandoned pipeline is not seen as being any different than for an operating pipeline. If it was not an issue previously it should not be an issue when the line is abandoned in place.</p> <p>No additional studies are recommended with respect to the potential conduit effect although this issue could be monitored as part of the study recommended in section 5.2.4 below.</p>	
14	Project - National Energy Board	National Energy Board, "Reasons for Decision, Manito Pipelines Ltd., MH-1-96, Facilities Abandonment,". June 1996.	http://publications.gc.ca/collections/Collection/NE22-1-1996-12E.pdf	<p>Manito noted that the pipeline is buried one metre below the surface and that, based on experience with smaller diameter pipelines, corrosion of the pipe would be gradual over time and only minimal surface disturbance would result. Manito acknowledged the potential for perforated or corroded pipe to create unnatural drainage, such as draining a slough or wetland or the flooding of an area as a result of water exiting the pipeline. Manito proposed to plug the line at locations likely to cause the pipeline to act as a conduit for groundwater or surface slough water between locations of different elevations. Different materials that could be used for plugs were investigated and Manito concluded that urethane foam would be the most suitable. Two areas with high water tables where the plugs could be installed were identified: the first location would be between the Blackfoot Station and Highway 16; and, the second location would be east of Highway 17. The specific locations would be selected so that access would not result in additional environmental adverse effects.</p>	
15	Project - National Energy Board	Line 3 Environmental Decommissioning Technical Report	https://www.neb-one.gc.ca/fetch_e.asp?id=A4E7E0	<p>Generic risks were categorized and mitigated through segmentation. Introduced idea of topographical highs, where natural conditions exist which would prevent the possible formation of water conduits. Within the context of the report.</p>	

16	Project - National Energy Board	Enbridge Response to: Group 1 Abandonment Cost Estimates Applications NEB File OF-AF-PCE 02 Information Request No. 2 Information requests to Enbridge Pipelines Inc. ("EPI")	https://docs.neb-one.gc.ca/l-eng/lisapi.dll/fetch/2000/90463/782060/782061/783089/795970/812141/B2-8b_-_Responses_to_NEB_IR_No_2_-_A2S6K9_.pdf?nodeid=812145&vernum=2	<p>a.2.vi) Potential for water conduits The potential for water conduits is a condition that may be present in both the abandonment in place and removal scenarios given the disturbance of soil which has occurred. The risks are not limited to a particular land use category or pipe size. Additionally, the consequences are linked to the level of cleanliness of the abandoned pipeline. The presence of abandoned in place pipeline infrastructure can create a conduit for water transmission within the pipeline once the pipeline degrades. Based on local conditions, water entering the pipeline could dewater, flood, erode, and/or sediment water features or low lying areas, and drain or charge aquifers and perched water tables. To prevent adverse effects to water features, and to minimize or eliminate the risk of the abandoned pipe providing a conduit, plugs would be installed at appropriate locations. Examples of plug material include concrete grout and polyurethane foam. Impermeable earthen plugs (i.e. clay) may also be considered; however, care must be taken to ensure they meet plug criteria including competent pipe adhesion, non-shrinkable, and impermeable. Removal of the pipeline would eliminate the potential issues for water conduit caused by the pipeline, however the potential for water conduits caused by the disturbed soil would remain. Additionally, the removal of the pipe would result in short term disruption of the land and potential degradation of soil resources, a potential increase in invasive weeds, risk of subsidence, and other similar impacts. Based on current information, the net impacts of leaving the pipe in place are expected to be less than the impacts associated with pipeline removal.</p> <p>In its application, Enbridge Pipelines Inc (EPI) made allowances to minimize the risk associated with water conduits. EPI has provided for a comprehensive abandonment preparation program which includes multiple cleaning tool inspections for initial in service cleaning as well as final cleaning, chemical treatment and final evaluation. Additionally, EPI has allowed for the segmentation of any pipeline to be abandoned in place by the installation of plugs at valve sites, the majority of special treatment locations, and stations. This results in an average pipeline segmentation of 2.5 kilometers. Final segmentation decisions will be determined at the time of actual abandonment and will be based on the results of site specific risk assessments.</p>	
17	Information Posting - National Energy Board	Pipeline Regulation in Canada: A Guide For Landowners and the Public	https://www.neb-one.gc.ca/prtcptn/Indwnrgd/Indwnrgd-eng.pdf	<p>The procedures are different for each abandonment depending on the location of the pipeline and the future proposed uses for the land. The company's abandonment plan usually addresses key issues that relate to public safety, environmental protection, and future land use. These include:</p> <ul style="list-style-type: none"> • land use management; • ground settling; • soil and groundwater contamination; • pipe cleanliness; • water crossings; • soil erosion; • utility and pipeline crossings; • creation of water conduits, where water travels through the pipeline; and • related pipeline equipment, e.g. risers, valves, piping, etc. 	
18	Information Posting - Canadian Environmental Pipeline Committee	Canadian Environment Pipeline Committee. The Life Cycle of Pipeline Watercourse Crossings in Canada: Questions and Answers. 2009	http://www.capp.ca/publications-and-statistics/publications/164366	No information	
19	Information posting - Canadian Energy Pipeline Association	CEPA – When a Pipeline Retires: 5 Things you Didn't know.	http://www.cepa.com/when-a-pipeline-retires-5-things-you-didnt-know	<p>4. As part of its application to the NEB, a company must submit its abandonment plan and that abandonment plans address such issues as:</p> <ul style="list-style-type: none"> -land use management. -whether that pipeline will be removed or abandoned in place. -ground settling -soil and groundwater contamination. -pipe cleanliness. -water crossings. -soil erosion. -utility and pipeline crossings. -the creation of water conduits, where water travels through the pipeline. -what will happen to pipeline equipment, e.g. risers, valves, piping, etc. 	
20	Project - National Energy Board Hearing Order	NEB - Hearing Order RH-2-2008 Land Matters Consultation Initiative Stream 3 - Reply Evidence of the Canadian Alliance of Pipeline Landowner's Associations (CAPLA)		<p>The potential to create water conduits as a result of the abandonment process is of concern as it could lead to unnatural drainage and material transport. This issue is primarily of concern when a pipeline is abandoned in place, since water will eventually infiltrate the pipe through perforations in the pipe wall caused by corrosion ... a previously stable low area could be flooded by volumes of water exiting from a perforated pipeline.</p> <p>This issue can be related to the concern for contamination and the protection of wetland systems. If water infiltrates the pipeline, the potential exists for that water to carry any residual contaminants left in the abandoned pipeline to some point of exit. The point of exit could be a watercourse, thereby contaminating the watercourse if contaminant levels are sufficiently great in volume and concentration at the point of exit. The possibility of soil contamination may also exist, depending on the nature of the contaminant transported through the pipeline"</p>	
21	Project - National Energy Board Hearing Order	NEB - Reasons for Decision Manito Pipelines Ltd. MH-1-96	http://publications.gc.ca/collections/Collection/NE22-1-1996-12E.pdf	<p>3.5 Pipeline Abandonment Procedures.</p> <p>Manito noted that the pipeline is buried one metre below the surface and that, based on experience with smaller diameter pipelines, corrosion of the pipe would be gradual over time and only minimal surface disturbance would result. Manito acknowledged the potential for perforated or corroded pipe to create unnatural drainage, such as draining a slough or wetland or the flooding of an area as a result of water exiting the pipeline. Manito proposed to plug the line at locations likely to cause the pipeline to act as a conduit for groundwater or surface slough water between locations of different elevations. Different materials that could be used for plugs were investigated and Manito concluded that urethane foam would be the most suitable. Two areas with high water tables where the plugs could be installed were identified: the first location would be between the Blackfoot Station and Highway 16; and, the second location would be east of Highway 17. The specific locations would be selected so that access would not result in additional environmental adverse effects.</p>	

22	Project - National Energy Board LMCI Hearing	CAEPLA - Pipeline Corrosion-Related Technical Issues and Long-Term Landowner Impacts	https://docs.neb-one.gc.ca/ll-eng/llisapi.dll/fetch/2000/90463/501473/501196/501199/504177/530137/C-1-6G_CAPLA_Response_to_LMCI_3_4_-_Appendix_6_-_Broadsword_Report_May_14_08_(A1G7Q3).pdf?_gc_lang=en&nodeid=530150&vernum=0	The paper cites conduits as a potential issue as based on the results of literature search as based on a review of the 1996 Discussion Paper.	
23	Project - National Energy Board Approval	National Energy Board Report - Enbridge Pipelines Inc. OH-002-2015 Volume II: Our Detailed Assessment	http://www.ceaa.gc.ca/050/documents/p80091/114138E.pdf	The Decommissioned Line 3 Pipeline Enbridge stated that the Decommissioned Line 3 Pipeline may function as a conduit to transport water, soil or residual contaminants, as the pipe deteriorates over time. Enbridge indicated that preventing the pipeline from becoming a conduit was an important consideration in designing its decommissioning plan. Enbridge stated that the key treatment measures to reduce the risks associated with the Decommissioned Line 3 Pipeline acting as a conduit are cleaning the pipeline prior to decommissioning, segmentation, maintaining CP, and ongoing RoW surveillance and maintenance.	
24	Project - Enbridge Line 3 Replacement Program	Line 3 - Environmental Decommissioning Technical Report	https://www.neb-one.gc.ca/fetch_e.asp?id=A4E7E0		
25	Alberta Regulation - Alberta Energy Regulator	Pipeline Act	www.qp.alberta.ca/documents/Acts/p15.pdf	No relevant content	
26	Regulation - Alberta Energy Regulator	Pipeline Rules	www.qp.alberta.ca/documents/Reqs/2005_091.pdf	(3) When a pipeline or part of a pipeline is discontinued, the licensee shall ensure that the pipeline or the part of the pipeline that is discontinued is (a) physically isolated or disconnected from any operating facility or other pipeline, (b) cleaned, if necessary, (c) purged with fresh water, air or inert gas, any of which may include the addition of internal corrosion inhibitors if the licensee is prepared to mitigate the environmental effects that could occur as a result of accidental release or spillage, (d) protected by suitable internal and external corrosion control measures, (e) not isolated or disconnected in a manner that results in an adjoining operating pipeline having fittings or connection points remaining that would create stagnant fluid traps or dead legs, unless (i) those locations are permanently accessible and subject to a scheduled inspection program, or (ii) the contained fluids are confirmed and documented as being non-corrosive, and (f) left in a safe condition.	While the act specifies that abandonment requires physical isolation from any active facilities, it does not prescribe any action specifically to address water conduits (see Section 82).
27	Regulation - Alberta Energy Regulator	Directive 056: Energy Development Applications and Schedules	www.aer.ca/documents/directives/Directive056_April2014.pdf	No relevant content	
28	Regulation - Alberta Energy Regulator	EUB Checklist for Minimum Technical Requirements for Pipeline Applications	www.aer.ca/documents/directives/Directive056_ChecklistMinimumTechReqsPipelineApps.pdf	No relevant content	
29	Regulation - Alberta Energy Regulator	Directive 066: Requirements and Procedures for Pipelines	http://www.aer.ca/documents/directives/Directive066.pdf	Section 42. Physically Isolated/Disconnected. The discontinued line or part of a pipeline is physically isolated or disconnected from any operating facility (CSA Standard Z662, Clause 10.13; Pipeline Regulation, Section 61(a,b,c,d); ID 2000-9; Directive 56) or disconnected from any operating facility (CSA Standard Z662, Clause 10.13; Pipeline Regulation, Section 61(a,b,c,d); ID 2000-9; Directive 56). Section 43. Pipeline left in Safe Condition. "Safe condition" means that there is no opportunity for explosive, flammable, poisonous, or environmentally damaging gases, liquids, or vapours to be emitted if the pipeline is damaged by any means.	No direction regarding water conduit risk or formation.
30	Regulation - Alberta Energy Regulator	Directive 077: Pipelines— Requirements and Reference Tools	http://www.aer.ca/documents/directives/Directive077.pdf	No relevant content	
31	Regulation - Alberta Environment and Parks	Environmental Protection and Enhancement Act (EPEA)	http://www.qp.alberta.ca/documents/acts/e12.pdf	No relevant content	
32	Regulation - Alberta Environment and Parks	EPEA Activities Designation Regulation	http://www.qp.alberta.ca/documents/regs/2003_276.pdf	No relevant content	
33	Guidance - Alberta Energy Board	Report 2013-B: Pipeline Performance in Alberta, 1990 - 2012	http://www.aer.ca/documents/reports/R2013-B.pdf	No relevant content	
34	Information Posting - Alberta Energy Regulator	ERCB Red Deer Field Centre – A Collaborative Workshop, Feb 14, 2013. Pipelines – Working together to Improve Compliance	https://www.aer.ca/documents/enforcement/ERCB_Pipeline_Workshop_20130214.pdf	No relevant content	
35	Academic Paper - Alberta	Environmental Considerations For Pipeline Abandonment: A Case Study from Abandonment of a Southern Alberta Pipeline (Swanson et al., 2010)	http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1614899	In theory, corroded pipelines could drain wetlands or change the flow of groundwater. In addition, if the pipeline has not been completely cleaned, there could be potential for contamination to travel to surface or groundwater. The identification and mitigation of pipeline segments with the potential to become conduits for water was a major concern for the owner of the TV #2 pipeline. In general, where potential was identified (i.e., steep slopes, wetlands or where test sections were found to be filled with water), the pipeline was removed or cut and capped at strategic locations. In wetlands, a plug was generally placed immediately downstream of the wet area, to prevent its drainage, and also at an appropriate location upstream of the wet area, to prevent potential contamination of the wet area.	The ATCO pipeline under discussion used a combination of measures to interpret where measures (segmentation) was to be installed to address water conduit risks.

36	Saskatchewan Regulation - Ministry of the Economy	The Pipelines Act, 1998	http://www.qp.gov.sk.ca/documents/English/Statutes/Statutes/P12-1.pdf	Regulations 25(1) The Lieutenant Governor in Council may make regulations: (h) prescribing measures for the protection of life, property or the environment to be taken in the construction, alteration, operation and abandonment of pipelines and the discontinuation of the operation of pipelines;	
37	Regulation - Ministry of the Economy	The Pipelines Regulations, 2000	http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/P12-1R1.pdf	Requirement under Section 9 Abandonment of a Pipeline Subsection b.(ii) the cutting of the pipeline at both ends at the buried depth and the welding of steel plates or caps over the openings;	
38	Manitoba Regulation - Manitoba Public Utilities Board	Oil and Gas Act	http://web2.gov.mb.ca/laws/statutes/ccsm/o034e.php#152(6)	No relevant content	
39	Regulation - Manitoba Public Utilities Board	Oil and Gas Regulations	http://www.gov.mb.ca/jem/petroleum/actsregs/home.html	No relevant content	
40	Regulation - Manitoba Public Utilities Board	The Gas Pipeline Act	http://web2.gov.mb.ca/laws/statutes/ccsm/g050e.php	No relevant content	
41	British Columbia Regulation - British Columbia Oil and Gas Commission	Oil and Gas Regulation Act, Pipeline Regulation	https://www.canlii.org/en/bc/laws/regu/bc-reg-281-2010/latest/bc-reg-281-2010.html	Obligations on cancellation or cessation of operations 11 The following requirements are prescribed with respect to a pipeline permit for the purposes of section 40 (e) of the Act: (a) abandon the pipeline in accordance with CSA Z662; (b) do everything referred to in section 19 (1) (a) to (g) of the Environmental Protection and Management Regulation.	See notes for next reference.
42	Regulation - British Columbia Ministry of the Environment	Environmental Protection and Regulation	https://www.canlii.org/en/bc/laws/regu/bc-reg-200-2010/latest/bc-reg-200-2010.html	19 (1) A person who carried out an oil and gas activity on an operating area and who no longer intends to do so must, as soon as practicable, restore the operating area by doing the following: (a) de-compacting any soils compacted by the oil and gas activity; (b) redistributing any retrievable surface soils that were removed from the operating area during construction so that the soil structure is restored, to the extent practicable, to its condition before the oil and gas activity was begun; (c) if the natural surface drainage pattern was altered by the carrying out of the oil and gas activity, restoring, to the extent practicable, the drainage pattern to its condition before the alteration; (d) re-vegetating any exposed soil on the operating area using seed or vegetative propagules of an ecologically suitable species that: (i) promote the restoration of the wildlife habitat that existed on the area before the oil and gas activity was begun, and (ii) stabilize the soil if it is highly susceptible to erosion; (e) removing any structure that was constructed to cross a stream, wetland or lake and ensuring that the site of the structure is in a stable condition; (f) stabilizing any cut slopes or fill slopes in wellsites and facility areas; (g) re-contouring bladed areas or excavations in pipeline corridors and seismic lines.	The important consideration is found within sections c and e: (c) if the natural surface drainage pattern was altered by the carrying out of the oil and gas activity, restoring, to the extent practicable, the drainage pattern to its condition before the alteration; (e) removing any structure that was constructed to cross a stream, wetland or lake and ensuring that the site of the structure is in a stable condition; Whether the regulation specifically was put in to address water conduit formation is not included in the act.
43	Guidance - BC Oil and Gas Commission	Pipeline Operations Manual	http://www.bcogc.ca/node/5859/download	Abandonment must adhere to CSA Z662 requirements.	
44	Project - British Columbia Utilities Board	FortisBC Energy Inc. (FEI) Application for a Certificate of Public Convenience and Necessity (CPCN) for Approval of the Lower Mainland Intermediate Pressure (IP) System Upgrade (LMIPSU) Projects (the Application) Response to Commercial Energy Consumers Association of British Columbia (CEC) Information Request (IR) No. 1	http://www.bcuc.com/Documents/Proceedings/2015/DOC_43285_B-6_FEI_Responses-to-CEC-IR1.pdf	In response to possible water conduit effects on an abandoned pipeline: Response to 45.1 "...the pipeline will be cut into 5 shorter sections, filled with a structural grout (where warranted) to prevent pipeline collapse and all open ends will be capped and sealed to prevent abandoned sections of pipe from acting as a water conduit and causing erosion."	
45	Ontario Regulation - Ontario Energy Board	Response to the Commercial Energy Consumers Association of British Columbia (CEC) Information Request (IR)	https://www.ontario.ca/laws/regulation/010210	No relevant content	
46	Regulation - Ontario - Technical Standards and Safety	TSSA Pipeline Abandonment Checklist	http://www.tssa.org/CorpLibrary/ArticleFile.asp?Instance=136&ID=6A3DAA-F948994881841311E46D807616	4. Has consideration been given to the effect of drainage in the area surrounding the abandoned pipeline, which may act as a conduit for ground water after the pipe is perforated by corrosion?	The guidance from TSSA definitely indicates concern for possible water conduits.
47	Regulation - Ontario	Ontario Energy Board, March 11, 2015 Union Gas Limited, Dawn Parkway Expansion Project EB-2014-0261. 2016.	http://www.rds.ontarioenergyboard.ca/webdrawer/webdrawer.dtl/webdrawer/rec/469448/view/	Clarified that the TSSA "while the TSSA has a Pipeline Abandonment "Checklist..." compliance may be expected but is not mandatory."	
48	Quebec Regulation - Régie Energie Quebec	Gas Distribution Act	http://www.canlii.org/en/qc/laws/stat/rsg-c-d-10/latest/rsg-c-d-10.html	No relevant content	
49	Regulation - Régie Energie Quebec	Regulations Respecting Gas and Public Safety	http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=3&file=/M_13_1/M13_1R1_A.HTM	No relevant content	

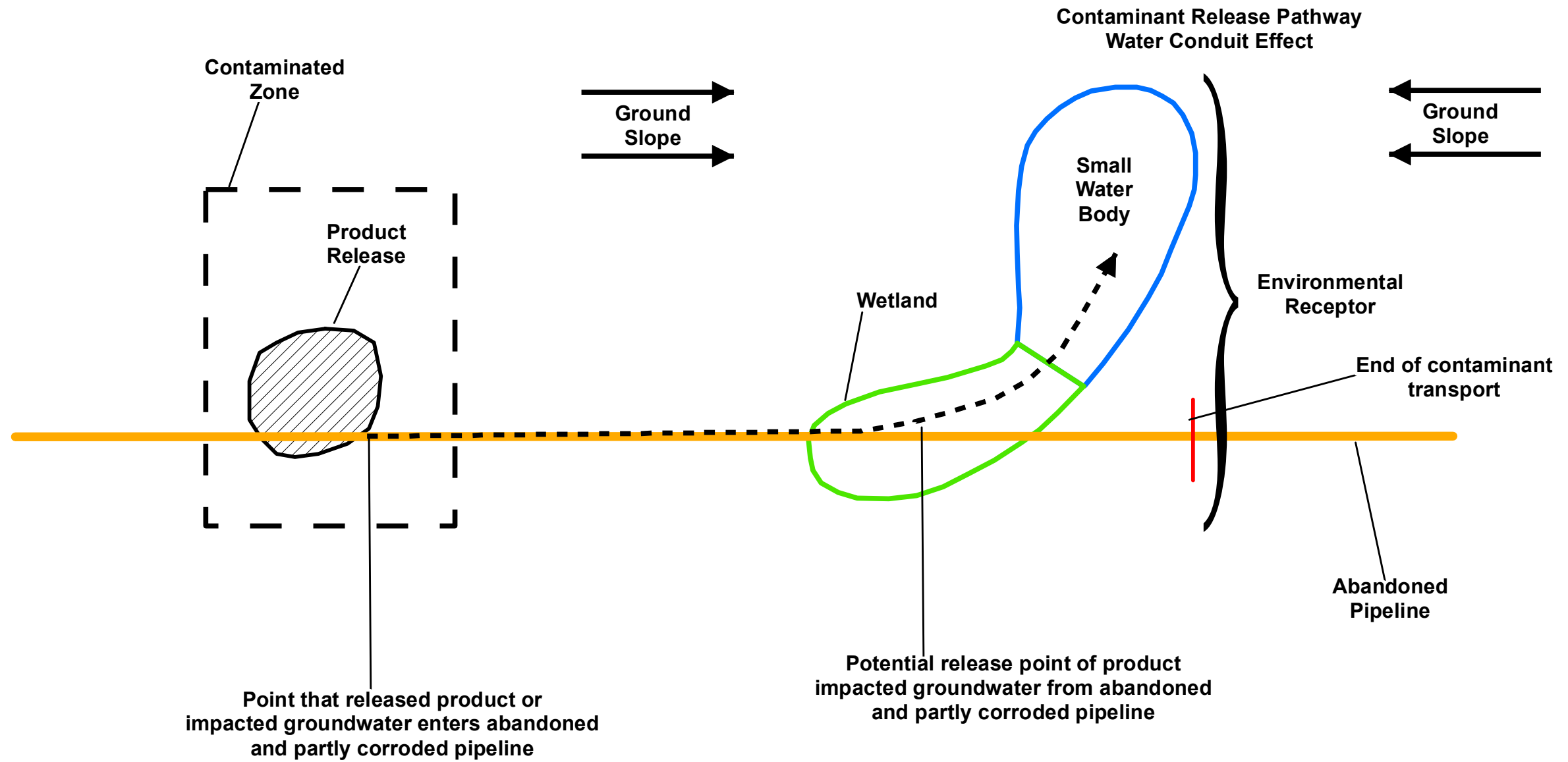
50	Nova Scotia Regulation - Nova Scotia Utility and Review Board	Pipeline Act	http://nslegislature.ca/legc/statutes/pipeline.htm	No relevant content	
51	Regulation - Nova Scotia Utility and Review Board	Pipeline Regulations	http://www.novascotia.ca/just/regulations/regs/pipregns.htm	No relevant content	
52	New Brunswick Regulation - New Brunswick Energy and Utilities Board	Pipeline Act	http://laws.gnb.ca/en/ShowPdf/cs/P-8.5.pdf	Article 48 - Discontinuance and abandonment of pipelines. An application made by a corporation under subsection 25(1) of the Act for leave to abandon the operation of a pipeline or a section of one shall include the rationale for the abandonment and the measures to be employed in the abandonment.	
53	Regulation - New Brunswick Energy and Utilities Board	Pipeline Regulations	http://laws.gnb.ca/en/ShowPdf/cr/2006-2.pdf	No relevant content	
54	United States Regulation - United States Federal	National Pipeline Mapping System Standards for Pipeline, Liquefied Natural Gas, and Breakout Tank Farm, Operator Submissions	https://www.npms.phmsa.dot.gov/Documents/Operator_Standards.pdf	No relevant content	
55	Regulation - United States Federal	49 Code of Federal Regulations 192.727 - Abandonment or deactivation of facilities.	http://www.law.cornell.edu/cfr/text/49/192.727	§ 192.727 Abandonment or deactivation of facilities. (b) Each pipeline abandoned in place must be disconnected from all sources and supplies of gas; purged of gas; in the case of offshore pipelines, filled with water or inert materials; and sealed at the ends. However, the pipeline need not be purged when the volume of gas is so small that there is no potential hazard. (f) Each abandoned vault must be filled with a suitable compacted material.	
56	Regulation - United States Federal	Operations and Maintenance Guidance 49 CFR 192 (Subparts L & M)	http://igs.nigc.ir/STANDS/BOOK/49.CFR.192.pdf	Same as above	
57	Regulation - United States Federal	30 CFR 250.1751 - How do I decommission a pipeline in place?	https://www.law.cornell.edu/cfr/text/30/250.1751	§ 250.1751 How do I decommission a pipeline in place? You must do the following to decommission a pipeline in place: You must do the following to decommission a pipeline in place: (a) Submit a pipeline decommissioning application in triplicate to the Regional Supervisor for approval. Your application must be accompanied by payment of the service fee listed in §250.125. Your application must include the following information. (1) Reason for the operation. (2) Proposed decommissioning procedures. (3) Length (feet) of segment to be decommissioned; and (4) Length (feet) of segment remaining. (b) Pig the pipeline, unless the Regional Supervisor determines that pigging is not practical; (c) Flush the pipeline; (d) Fill the pipeline with seawater; (e) Cut and plug each end of the pipeline; (f) Bury each end of the pipeline at least 3 feet below the seafloor or cover each end with protective concrete mats, if required by the Regional Supervisor; and (g) Remove all pipeline valves and other fittings that could unduly interfere with other uses of the OCS.	
58	Regulation - United States Federal	U.S. Fish & Wildlife USFWS Consultation Document for the Nisource MSHP. Biological Opinion, Incidental Take Statement, Information Consultation, & related documents.	http://www.fws.gov/midwest/Endangered/permits/hcp/nisource/pdf/NisourceFinalBOsignedNoAppendices.pdf	Refers to abandonment in place with respect to effects and mitigation on specific species.	

59	Regulation - California	<p>§ 124. Abandoned Pipelines and Conduits. 23 CA ADC § 124BARCLAYS OFFICIAL CALIFORNIA CODE OF REGULATIONS</p>	<p>https://govt.westlaw.com/calregs/Document/115631A50FB2D11DEB558EB7A3F18BAB6?viewType=FullText&originContext=documenttoc&transitionType=CategoryPageItem&contextData=sc.Default</p>	<p>23 CCR § 124</p> <p>§ 124. Abandoned Pipelines and Conduits.</p> <p>(a) Abandoned pipelines, conduits, and all appurtenances (such as pumps, standpipes, or positive closure structures) that are located within a levee section, within the projected levee section, or within ten (10) feet of the levee toes shall be completely removed, when practical, and disposed of outside the floodway.</p> <p>(1) When the invert of an abandoned pipeline or conduit within a levee is above the design flood plane elevation, the pipeline or conduit must be removed.</p> <p>(2) An abandoned pipeline or conduit located within one (1) foot of the surface of the levee slope shall be removed.</p> <p>(3) When the invert of an abandoned pipeline or conduit within a levee is six (6) feet or less below the design flood plane elevation, the board may require the removal of the pipeline or conduit.</p> <p>(4) The side slopes of an excavation to remove an abandoned pipeline or conduit from within a levee must be one (1) foot horizontal to one (1) foot vertical or flatter.</p> <p>(5) After any pipeline, conduit, or appurtenance is removed from a levee, approved backfill shall be keyed into the levee section with each lift and compacted in four- (4) to six- (6) inch layers with a relative compaction of not less than ninety (90) percent, per ASTM D1557-91, dated 1991, which is incorporated by reference and above optimum moisture content.</p> <p>(b) Abandonment of pipelines and conduits within a floodway must be in a manner consistent with the following:</p> <p>(1) After any pipeline, conduit or appurtenance is removed from a floodway, open-trench backfill must be placed in a manner consistent with the local conditions. Erosive stream reaches will require methods that compact the backfill to at least the density of that of adjacent soils. Compaction tests by a certified soils laboratory may be required to verify compaction within the floodway.</p> <p>(2) Abandoned pipelines or conduits within the berm and within thirty (30) feet of the top of the streambank must not be filled with concrete but may be removed if exposed by bank erosion.</p> <p>(c) If it is determined by the board that it is impractical or detrimental to the levee to remove an abandoned pipeline or conduit from a levee section, the pipeline or conduit must be completely filled with concrete.</p> <p>(1) Concrete to be used to fill an abandoned pipeline or conduit must be a three- (3) sack cement mix, or equivalent, with aggregate having a maximum size of three-eighths (3/8) inch, and a water content sufficient to produce a six- (6) to eight- (8) inch slump.</p> <p>(2) A detailed plan for filling an abandoned pipeline or conduit with concrete may be required to be submitted for approval by the board prior to start of work.</p> <p>(3) A pipeline or conduit to be filled with concrete must have a minimum cover of three (3) feet below the waterward levee slope.</p> <p>(4) See Figure 8.07 for illustrated details on sealing abandoned pipelines and conduits.</p> <p>(d) Concrete pipes may be plugged with concrete at each end as an alternative to complete filling. The length of each plug shall be a minimum of two (2) feet or twice the diameter of the pipe, whichever is greater.</p>	
60	Regulation - Colorado	<p>Colorado Oil & Gas Conservation Commission. April 1, 2009. Pipeline Regulations.</p>	<p>https://cogcc.state.co.us/RR_Docs_new/rules/1100Series.pdf</p>	<p>1103. ABANDONMENT Each pipeline abandoned in place shall be disconnected from all sources and supplies of natural gas and petroleum, purged of liquid hydrocarbons, depleted to atmospheric pressure, and cut off three (3) feet below ground surface, or the depth of the pipeline, whichever is less and sealed at the ends. T</p>	
61	Regulations - Massachusetts	<p>Massachusetts Court System, 220 CMR 107, Abandonment of Gas Service Lines and Leakage Survey Procedures. DEPARTMENT OF TELECOMMUNICATIONS AND ENERGY</p>	<p>http://www.mass.gov/courts/docs/lawlib/220-229cmr/220cmr107.pdf</p>	<p>No relevant content</p>	
62	Regulations - Massachusetts	<p>220 CMR: DEPARTMENT OF TELECOMMUNICATIONS AND ENERGY CMR 113.00: OPERATION, MAINTENANCE, REPLACEMENT, AND ABANDONMENT OFCAST-IRON PIPELINES</p>	<p>http://www.mass.gov/courts/docs/lawlib/220-229cmr/220cmr113.pdf</p>	<p>No relevant content</p>	
63	Regulations - North Dakota	<p>North Dakota Department of Mineral Resources, North Dakota Rulebook for Oil And Gas. 2016</p>	<p>https://www.dmr.nd.gov/oilgas/rules/rulebook.pdf</p>	<p>No relevant content</p>	
64	Standards - American Petroleum Institute	<p>Environmental Protection for Onshore Oil and Gas Production Operations and Leases. API recommended Practice 51R First edition, July 2009.</p>	<p>http://www.api.org/~media/files/policy/exploration/api_rp_51r.ashx</p>	<p>Discussion concerning well decommissioning requiring suitable plugging. No reference to pipelines.</p>	
65	Project - Wisconsin Department of Natural Resources	<p>Sandpaper Pipeline and line 3 Replacement Project, Wisconsin Draft Environmental Impact Statement Vol. 1</p>	<p>http://dnr.wi.gov/topic/EIA/documents/Enbridge/SPL3_Draft_EIS_Vol_1.pdf</p>	<p>Chapter 4.3.2.1</p> <p>It is recommended that the Applicant provide an Abandonment Plan to the DNR (Minnesota Department of Natural Resources) prior to the start of abandonment that outlines the precise steps that would be taken during the abandonment process and that addresses the following recommendations:</p> <p>-Agree to the placement of plugs at strategic locations near waterbody and welland crossings, at the boundaries of sensitive land uses (e.g., natural areas, parks), and at the top and bottom of steep slopes.</p>	

66	Guideline - Gas Piping Technology Committee	Guide for Gas Transmission and Distribution Piping Systems	https://puc.sd.gov/commission/pipelinesafety/seminars/2011/presentation/gaspipingtechnologycommittee.pdf	No relevant content	
67	Information posting - ViaData	Viadata: What Regulations Apply to Idle Pipelines	https://viadata.wordpress.com/2009/11/05/what-regulations-apply-to-idle-pipelines/	No relevant content	
68	Information Posting - Right of Way Magazine - United States	David Howell, Oct. 2007. The Search for Abandoned Pipelines	https://www.irwaonline.org/eweb/upload/0907-2.pdf	No relevant content	
69	Information Posting - Pipeline & Gas Journal	Pipeline & Gas Journal. Sept. 2014. Who owns Abandoned Pipelines?	http://cogcc.state.co.us/documents/Reg/Rules/LATEST/1100Series.pdf	No information.	
70	Information posting - Oil and Gas Journal	Oil & Gas Journal, July 2002.	www.tetratrac.com/getFile.asp?File_Content_ID=1544	Discusses abandonment of undersea pipelines, in this case they are to be left <i>in situ</i> with no additional measures.	
International					
United Kingdom					
71	Regulation - United Kingdom	A guide to the Pipelines Safety Regulations 1996. Health and Safety Executive.(updated to 2012).	http://www.hse.gov.uk/pUbns/priced/182.pdf	Regulation 14 65 Depending on the physical dimensions of an onshore pipeline and its location, under the general provisions of the HSW Act, it may be necessary to consider the risk of the pipeline corroding and causing subsidence or acting as a channel for water or gases.	
Thailand					
72	Standards - Petroleum Institute of Thailand	PTIT (Petroleum Institute of Thailand). Onshore Pipelines Decommissioning guideline	http://www.ptit.org/download/webdocument/Attachment%20F%20(Draft%20Onshore%20Pipelines%20Decommissioning%20Guideline).pdf	6.3.2 Leave in in-situ Due to the impact associated with removing buried pipelines, it is expected that most subsurface pipelines will be left in situ subject to, but not limited to, the following conditions: <ul style="list-style-type: none"> • The pipeline has been flushed and cleaned in accordance to 6.4.1 and if required, decontaminated to the recommended levels and the verification process is followed as per 6.4.2 and 6.4.3 respectively. • Publicity to the relevant local authorities must be given with regards to depth, position, size and condition of any pipelines left in situ to ensure the pipelines do not become an obstruction or hindrance to any future land management activities and utilities; • Where applicable, suitable measures (such as cement plugs) are taken in sloping areas to ensure the pipeline does not become a conduit for water; • Best Available Technology are used in the appropriate areas to prevent the risk of future subsidence or erosion (road crossings, water crossings, steep slopes); • It is accepted by the designated authorities, in consultation with landowners, with the precondition that a Re-plantation and Reinstatement Plan together with a monitoring and audit program is prepared and implemented to ensure the process to complete remediation. 	
Australia					
73	Standards - Australia	The Australian Pipeline Industry Association Ltd. Oct. 2013. On shore Pipelines Code of Environmental Practice	http://www.apia.net.au/wp-content/uploads/2013/01/131014_APIACoEP_2013_Final.pdf	Section 8.2 Rehabilitation and Monitoring <ul style="list-style-type: none"> • Consideration should be given to filling the pipeline with cement slurry or other appropriate material to prevent the pipeline acting as a water conduit, or collapsing to cause surface subsidence. 	
74	Project - Australia	Arrow Bowen Gas Project EIS. 29 – Decommissioning and Rehabilitation	http://www.arrowenergy.com.au/_data/assets/pdf_file/0018/3852/Section_29-Decommissioning-and-Rehabilitation.pdf	No relevant information.	
75	Project - Australia	Arrow Bowen Pipeline EIS. 3.6.2 – Decommissioning. 2013.	https://www.arrowenergy.com.au/_data/assets/pdf_file/0015/2256/Arrow20Bowen20Pipeline20EIS.pdf	Two options for the decommissioning of the line were proposed. <ul style="list-style-type: none"> -Moth-balling – this would involve depressurising the pipeline, capping and filling with an inert gas (such as nitrogen) or water with corrosion inhibiting chemicals. The cathodic protection would be maintained to prevent the pipe corroding; and; -Abandonment – this could involve purging the pipe of natural gas, disconnecting it from the manifolds and removing all above ground facilities. The pipe would then be filled with water and left to corrode in-situ. Removing the pipe from the ground is unlikely to be an environmentally- or commercially-viable option. A detailed rehabilitation program would be developed and implemented in consultation with landholders and the regulatory agencies at the time of abandonment. 	


76	Non - Regional Reference Textbook -	<i>E. Shashi Menon, Pipeline Planning and Construction Field Manual, 2011</i>	http://store.elsevier.com/Pipeline-Planning-and-Construction-Field-Manual/E.-Shashi-Menon/isbn-9780123838674/	No reference to abandonment.	
77	Reference - Textbook	R. Winston Revie, Oil and Gas Pipelines: Integrity and Safety Handbook, 2015.		Section 47.4.4 This textbook quotes discussed water conduits however does not bring any new information forward. Refers directly to	
78		SEARCH ENGINE	http://proceedings.asmedigitalcollection.asme.org/		
79	Standards - ANSI	ISO 13623:2009 Petroleum and natural gas industries - Pipeline transportation systems		THIS WAS NOT ACCESSED BUT MAY BE PERTERNENT FOR GUIDANCE	

FIGURES

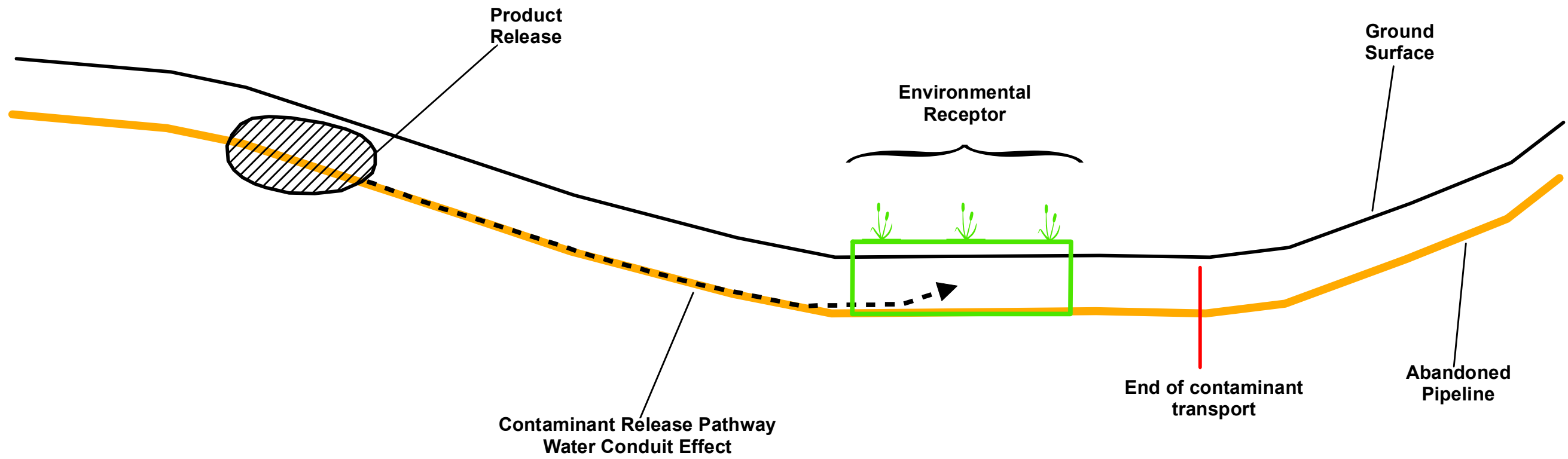


NOT TO SCALE
PLAN VIEW

NOTE:
SEE FIGURE 2 FOR PROFILE


Water Conduit Effect		
Contaminated Site Scenario		
Prepared By-Date: JRM - 4/17/2017		Figure: 1
Checked By-Date: DP - 4/17/2017		
Project Number: EE26423		

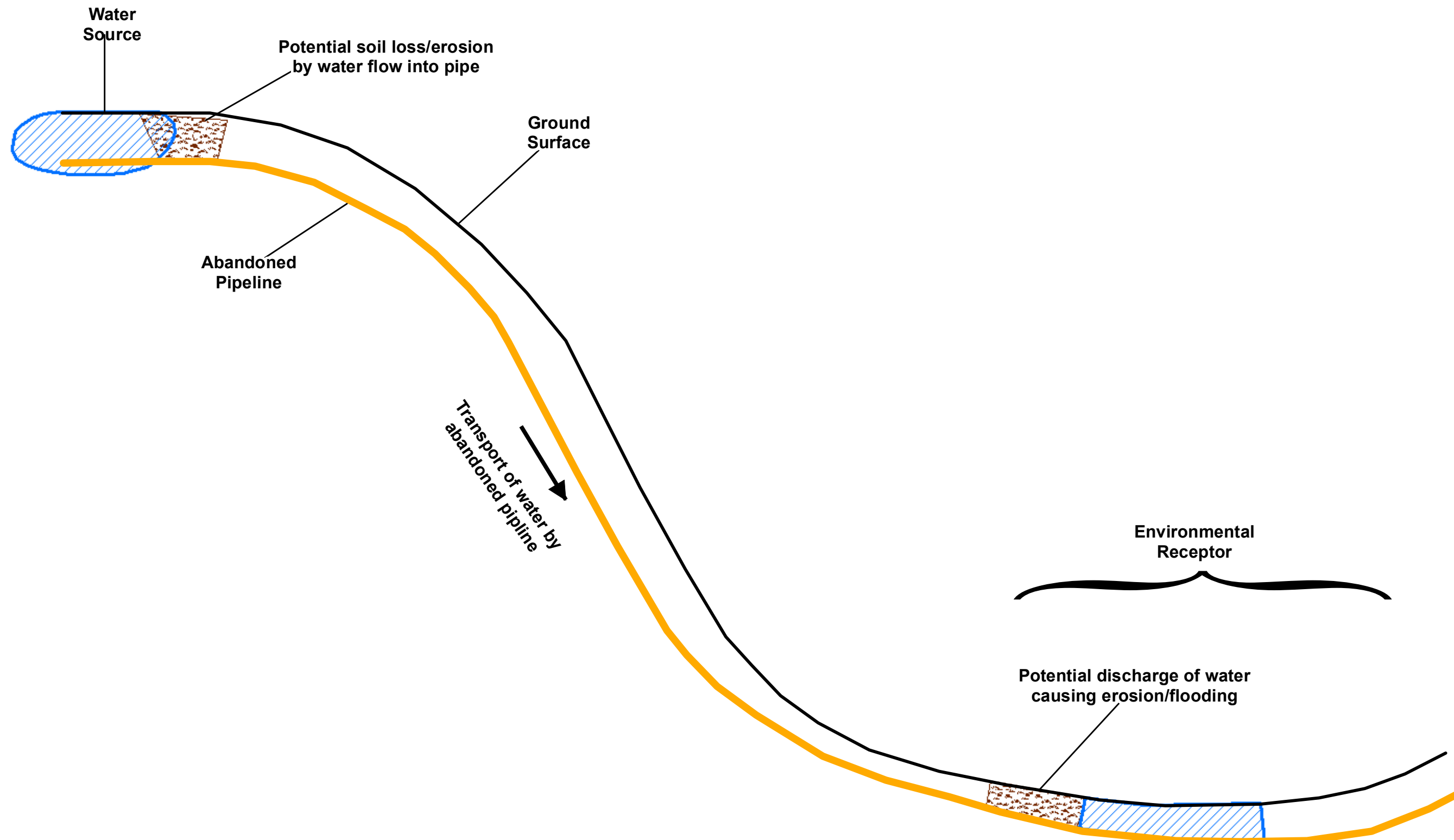
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NOT TO SCALE
PLAN VIEW

NOTE:
SEE FIGURE 1 FOR PLAN VIEW

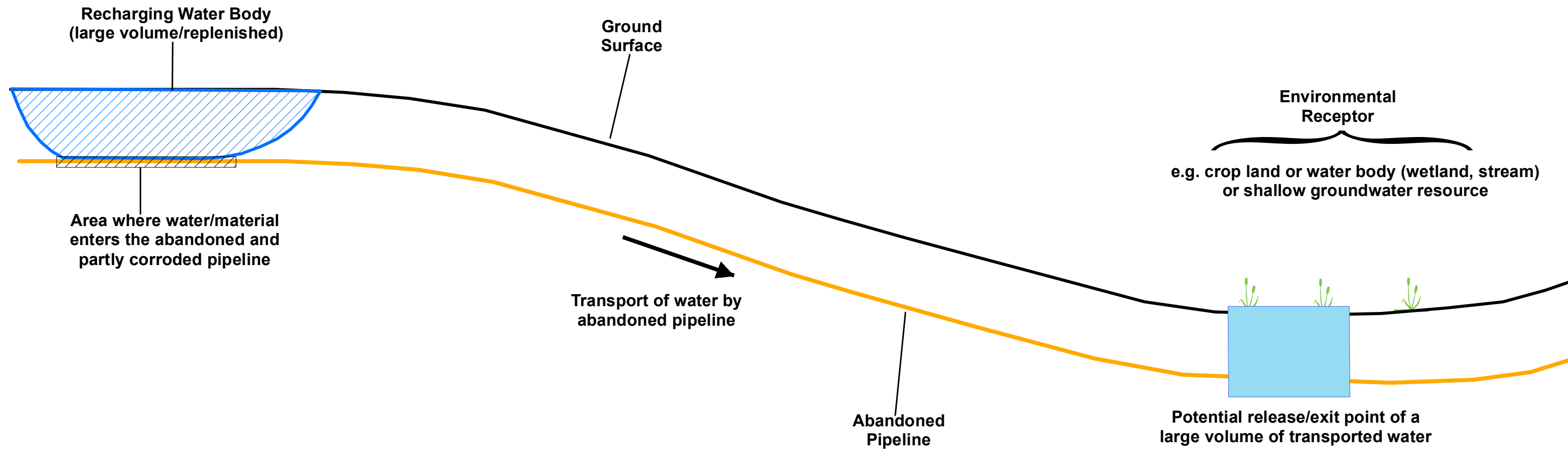
Water Conduit Effect		
Contaminated Site Scenario		
Prepared By-Date: JRM - 4/17/2017		Figure: 2
Checked By-Date: DP - 4/17/2017		
Project Number: EE26423		




NOT TO SCALE
PLAN VIEW

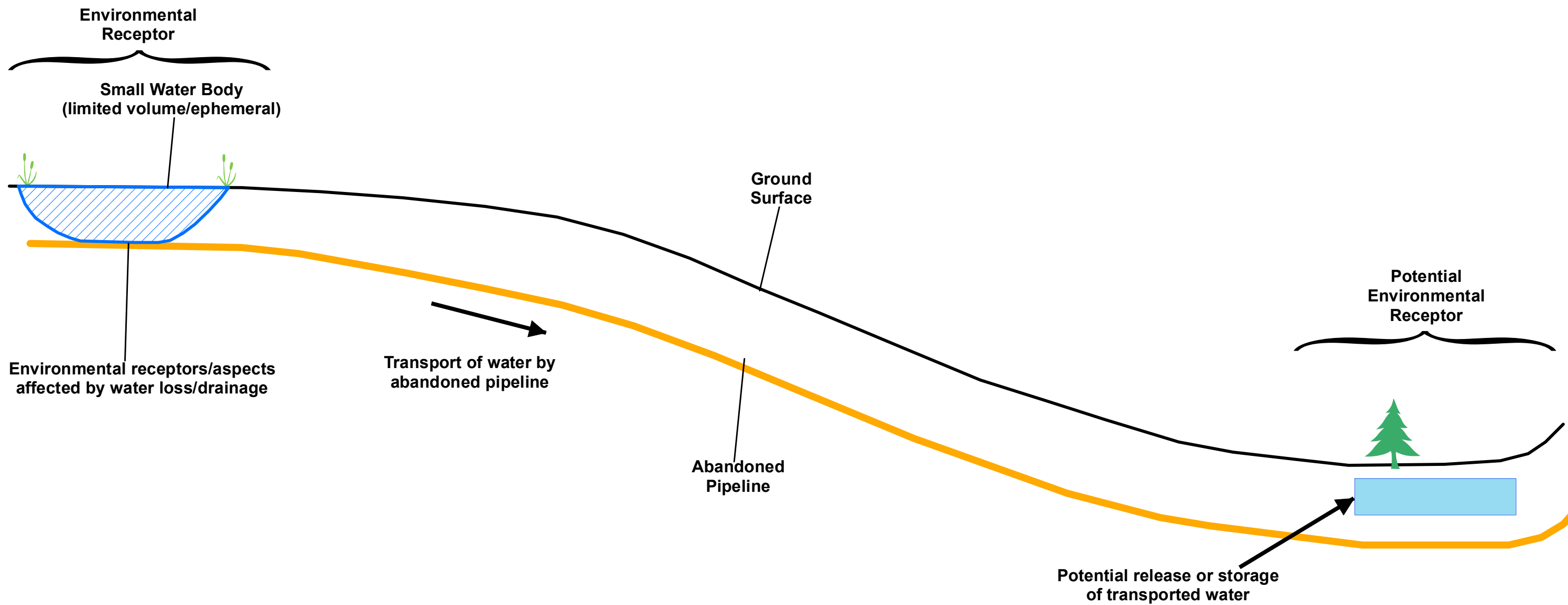
Water Conduit Effect		
Incline Scenario		
Prepared By-Date: JRM - 4/17/2017		Figure: 3
Checked By-Date: DP - 4/17/2017		
Project Number: EE26423		

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PLAN VIEW

Water Conduit Effect		
Recharging Water Body Scenario		
Prepared By-Date: JRM - 4/17/2017		Figure: 4
Checked By-Date: DP - 4/17/2017		
Project Number: EE26423		



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PLAN VIEW

Water Conduit Effect		
Small Water Body Scenario		
Prepared By-Date: JRM - 4/17/2017		Figure: 5
Checked By-Date: DP - 4/17/2017		
Project Number: EE26423		