Control Effectiveness Assessment of Solvent Injection Processes

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Alberta Energy Regulator
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1 Introduction

Solvent injection processes, assessed in this report, are bitumen recovery technologies that involve **injecting solvents** (such as propane, diluent or other hydrocarbons) or **co-injecting solvents with steam** into a reservoir to produce bitumen reserves.

1.1 Background

A screening level risk assessment, which was completed in September 2017, identified potential failure/release scenarios associated with the use of solvents in Steam-Assisted Gravity Drainage (SAGD) processes and determined their level of risk. This information can be used in risk-informed decision making and discussions for solvent injection processes:

- 20 potential failure/release scenarios that could result in the release of Contaminate(s) of Potential Concern (CoPCs) from solvent injection processes were identified.
- 16 out of the total 20 potential failure/release scenarios with associated potential transport pathways and exposure routes were identified as lower band risk scenarios, for which the probability of exposure is very low or the potential magnitude of exposure is negligible.
- 4 out of the total 20 failure/release scenarios have potential transport pathways and exposure routes ranked as middle band risk scenarios with the consideration of AER's existing regulatory controls. These middle band risk scenarios include:

    1) Caprock fracture - e.g., slow release of fluid to the surface
    2) Caprock and overlaying formation fracture – e.g., Total Joslyn incident
    3) Loss of containment from pipeline transportation – leaks
    4) Loss of containment from pipeline transportation – break/rupture

1.2 Objective

The objective of this work is to assess the effectiveness of regulatory controls currently in place for the following four middle band risk scenarios (**Table 1**).

Table 1: The four middle band risk scenarios

No.	Potential Source		Potential Failure/Release Scenarios
	Activity	Potential Substances	
1	Solvent Injection Process – subsurface activities	Solvent, Bitumen, Produced Water	Caprock fracture - e.g., slow release of fluid to the surface
2	Solvent Injection Process – subsurface activities	Solvent, Bitumen, Produced Water	Caprock and overlaying formation fracture – e.g., Total Joslyn incident
3	Pipeline transportation	Crude Oil, Diluent, Dilbit, Produced Water, Steam	Loss of containment from pipeline transportation - leaks
4	Pipeline transportation	Crude Oil, Diluent, Dilbit, Produced Water, Steam	Loss of containment from pipeline transportation – break/rupture

2 Control Effectiveness Assessment

The assessment was conducted by members of AER's Industry Operations - In Situ group and Pipelines group, and Enterprise Risk Management team.

2.1 Methodology

The methodology used in this assessment was modified based on the AER's *Guidelines for Control Effectiveness Assessment*. The effectiveness of existing regulatory controls was assessed based on the following two attributes:

1) **Control Performance** – whether the control performs the way it was intended to perform, and

2) **Control Dependability** – whether the control is dependable every time it is used.

The evaluation criteria for Control Performance and Control Dependability are summarized in **Table 2** and **Table 3**[1].

[1] Table 2 and Table 3 are from the AER's *Guidelines for Control Effectiveness Assessment*

Table 2: Control Performance Evaluation Criteria

Score	Performance Effectiveness	Evaluation Factors for Control Performance
5	Control is more than 95% effective	• The control achieves its performance targets almost all of the time. • The performance targets are appropriate for the type of risk modification effect that is trying to be achieved.
4	Control is between 60-94% effective	• The control achieves its performance targets the majority of the time. • The performance targets may be generally appropriate for the type of desired risk modification, but have minor gaps.
3	Control is between 30-59% effective	• The control achieves its performance targets some of the time. • The performance targets may be appropriate for the type of desired risk modification, but have moderately large gaps.
2	Control is less than 30% effective	• The control rarely achieves its performance targets. • The performance targets may not be appropriate for the type of risk modification that is desired.
1	Not able to assess	• There is insufficient reliable information available to determine if the control is effectively achieving its performance targets

Table 3: Control Dependability Evaluation Criteria

Score	Dependability	Evaluation Factors for Dependability
5	Control is more than 95% dependable	• The control is dependable at almost all times. • The control is largely independent of the need for human intervention, or requires very limited human interaction.
4	Control is between 60-94% dependable	• The control is dependable the majority of the time. • The control is somewhat independent of the need for human intervention, or requires only minor-moderate human interaction.
3	Control is between 30-59% dependable	• The control is dependable some of the time. • The control is somewhat dependent on human intervention, or requires moderate-high levels of human interaction.
2	Control is less than 30% dependable	• The control is rarely dependable. • The control is somewhat heavily dependent on human intervention, or requires high levels of human interaction.
1	Not able to assess	• There is insufficient reliable information available to determine if the control is dependable.

The scores for each attribute, as determined from **Table 2** and **Table 3**, were multiplied by pre-determined weightings showing in **Table 4**. Once the individual attributes have been assessed and weighted, the overall level of control effectiveness were determined according to **Table 5**.

Table 4: Weightings for Each Attribute[2]

Assessment Attribute	Weighting to be applied
Control Performance	64%
Control Dependability	36%

Table 5: Description of the Five Levels of Control Effectiveness[3]

Score Range	Level of Effectiveness	Description of Control Effectiveness Level
4.5 - 5	Fully Effective	Controls are generally: • Performing effectively at almost all times • Dependable at almost all times
3.5 - 4.5	Substantially Effective	Controls are generally: • Performing effectively the majority of the time • Dependable the majority of the time
2.5 - 3.5	Partially Effective	Controls are generally: • Performing effectively some of the time • Dependable some of the time
1.5 - 2.5	Largely Ineffective	Controls are generally: • Rarely performing effectively • Rarely dependable
1 - 1.5	None or Effectiveness Not Able to Be Assessed	Controls do not exist or it is not possible to assess if: • The control is performing • The control is dependable

[2] We normalized the weightings for Control Performance and Control Dependability from the AER's *Guidelines for Control Effectiveness Assessment*, and applied them in this assessment.

[3] Table 5 is from the AER's *Guidelines for Control Effectiveness Assessment*

2.2 Control Suite Identification

In identifying a suite of controls, we considered the following classifications:

- Enablers, which include policies, regulations, rules, and directives
- Preventative controls, which are designed to prevent a risk event from occurring in the first place, or to limit the extent of the damage that could be caused if a risk event were to happen
- Detective controls, which are designed to identify when a risk event is occurring, or is about to occur
- Corrective controls, which are designed to stop or limit the loss associated with a risk event

When controls are dependent on each other, the partial or full failure of one control can reduce the performance of all the dependent controls. Therefore, we assessed the effectiveness of the whole control suite instead of the effectiveness of each individual control or enabler. Table 6 summarizes the suite of controls for each of the four middle band risk scenarios.

Table 6: Control Suite Identification

No.	Risk Scenarios	Type of Operation	Suite of Controls
1	• Caprock fracture (e.g., slow release of fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	Shallow area (in accordance with *Directive 086*)	• *Directive 23: Guidelines Respecting and Application for a Commercial Crude Bitumen Recovery and Upgrading Project* (*Directive 023*) and/or *Directive 086*: *Reservoir Containment Application Requirements for Steam-Assisted Gravity Drainage Projects in the Shallow Athabasca Oil Sands Area*(*Directive 086*) - Application review process (e.g., Maximum Operating Pressure, geological data) - Approval condition (e.g., limit injection pressure) - Caprock monitoring (e.g., change in geological conditions) • Operational surveillance plan - Maximum Operating Pressure audits - Compliance assurance activities • Annual surveillance for *Directive 054*: *Performance Presentations, Auditing, and Surveillance of In Situ Oil Sands Schemes*(*Directive 054*) • *Directive 051: Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements* (*Directive 051*) • Field inspection
2	• Caprock fracture (e.g., slow release of	Non-shallow area: Steam-Assisted Gravity Drainage	• *Directive 023* - Application review process (e.g., Maximum Operating Pressure, geological data)

No.	Risk Scenarios	Type of Operation	Suite of Controls
	fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	(SAGD)	- Approval condition (e.g., limit injection pressure) - Caprock monitoring (e.g., change in geological conditions) • Operational surveillance plan - Maximum Operating Pressure audit - Compliance assurance activities • Annual surveillance for *Directive 054* • Industry engagement • *Directive 051* • Field inspection
3	• Caprock fracture (e.g., slow release of fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	Non-shallow area: High Pressure Cyclic Steam Stimulation (HP CSS)	• *Directive 023* - Application review process (e.g., geological data) - Approval condition (e.g., limit injection volume) - Caprock monitoring (e.g., change in geological conditions) • Annual surveillance for *Directive 054* • Industry engagement (e.g., monthly meetings) • Surveillance of Grand Rapids pressure anomalies and intervention of high-pressure CSS (HPCSS) operators
4	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Crude oil transmission pipelines	Enablers: • *Pipeline Act and Pipeline Rule* • *Directive 077: Pipelines – Requirements and Reference Tools (Directive 077), Directive 056: Energy Development Applications and Schedules (Directive 056), Directive 071:Emergency Preparedness and Response Requirements for the Petroleum Industry (Directive 071)* • Canadian Standard Association publications, including *CSA Z662 – Oil and Gas Pipeline Systems, CSA Z245.1 – Steel pipe, CSA Z245.11 – Steel fittings,* et cetera • Alberta Boilers Safety Association (ABSA) standards and codes Preventative controls: • Pipeline design, including materials, installation, construction, operation, maintenance, integrity management, repair, testing, welding/joining Detective controls: • Inspection, corrosion monitoring • Welding inspection • Right of way surveillance • Automated leak detection • Incident reporting

No.	Risk Scenarios	Type of Operation	Suite of Controls
			Corrective controls: • Field inspection, audits, and investigation • Compliance assurance activities
5	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	LVP products pipelines, including diluent and dilbit	Same as above
6	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Salt water pipelines (for produced water)	Same as above
7	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Miscellaneous gas pipelines (for steam)	Save as above

2.3 Control Suite Effectiveness

The overall effectiveness of identified suite of controls was assessed using the criteria described in **Section 2.1** and summarized in **Table 7**.

Table 7: Control Suite Effectiveness Results

No.	Risk Scenarios	Type of Operation	Control Performance	Control Dependence	Control Effectiveness
1	• Caprock fracture (e.g., slow release of fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	Shallow area	5: More than 95% effective	4: between 60-94% dependable	4.64: Fully Effective

2	• Caprock fracture (e.g., slow release of fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	Non-shallow area: SAGD	5: More than 95% effective	4: between 60-94% dependable *Note: based on the operations that the AER audited, the control suite is more than 95% dependable. However, the AER hasn't audited all the operations.*	4.64: Fully Effective
3	• Caprock fracture (e.g., slow release of fluid to the surface), and • Caprock and overlying formation fracture (e.g., Total Joslyn incident)	Non-shallow area: HP CSS	3.5: between 45-75% effective *Note: CSS has no limits on injection pressure except for one operator where the FTS events have taken place*	3: between 30–59% dependable *Note: the requirements rely on lots of human intervention*	3.32: Partially Effective
4	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Crude oil transmission pipelines	4.5: between 75-95% effective *Note: transmission lines are generally managed better than non-transmission lines*	4: between 60-94% dependable *Note: Although in situ operators are less experienced in pipeline operations, their infrastructure is newer and has good automated detections and operators around.*	4.32: Substantially Effective

5	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Diluent or dilbit pipelines (classified as LVP products pipelines)	4: between 60 – 94% effective *Note: LVP product pipelines generally has higher failure rate*	4: between 60-94% dependable *Note: in situ operators are less experienced in pipeline operations; however, the infrastructure is new (was built more robustly); and large operations have good automated detections and operators around.*	4: Substantially Effective
6	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Produced water pipelines (classified as salt water pipeline)	4: between 60 – 94% effective *Note: salt water pipelines generally has higher failure rate*	4: between 60-94% dependable *Note: in situ operators are less experienced in pipeline operations; however, the infrastructure is new (was built more robustly); and large operations have good automated detections and operators around.*	4: Substantially Effective
7	Loss of containment from pipelines: 1) leaks 2) Breaks/ruptures	Steam pipelines (classified as Miscellaneous gas pipelines)	4.5: between 75 -95% effective *Note: steam pipelines are generally managed better*	4: between 60-94% dependable *Note: in situ operators are less experienced in pipeline operations; however, the infrastructure is new (was built more robustly); and large operations have good automated detections and operators around.*	4.32: Substantially Effective

3 Key Findings and Recommendations

The control effectiveness assessment identified a number of key findings:

1) Existing regulatory controls are considered as **fully effective** for:

    a. Caprock fracture (e.g., slow release of fluid to the surface) and caprock and overlying formation fracture (e.g., Total Joslyn incident) for shallow area operations involving solvent injection processes, and,

    b. Caprock fracture (e.g., slow release of fluid to the surface) and caprock and overlying formation fracture (e.g., Total Joslyn incident) for non-shallow area SAGD operations involving solvent injection process.

2) Existing regulatory controls are considered as **substantially effective** for Loss of containment (leaks and/or breaks/ruptures) for :

    a. diluent or dilbit pipelines,

    b. produced water pipelines,

    c. crude oil transmission pipelines, and

    d. for steam pipelines.

3) Existing regulatory controls are considered as **partially effective** for caprock fracture (e.g., slow release of fluid to the surface) and caprock and overlying formation fracture (e.g., Total Joslyn incident) for non-shallow area HP CSS operations involving solvent injection processes.

Based on the above key findings, we made the following recommendations:

1) For pipelines, in order to have a better understanding on the existing regulatory controls, the AER could:
    - conduct more detailed operations and construction inspections on in situ operators under the Pipeline Risk Program
    - conduct assessments on in situ operators related to Safety Loss Management System
    - Share this report with Environment and Operational Performance (E&OP) Branch staff who conduct inspections and audits at in-situ facilities
    - Share the above information with the Integrated Decision Approach (IDA) team in their development of system rules associated with pipeline compliance assurance activities

2) For HP CSS operations, whether having solvent or not, limiting the injection volume and enhancing the monitoring are key controls to reducing the associated risks. When non-shallow area HP CSS operation is proposed to involve solvent injection, the AER should:

- maintain monthly meetings with HP CSS operators in dealing with any high risk operational issues;
- continue to scrutinize HP CSS operator’s responses to Grand Rapids pressure anomalies and/or injectivity events; and,
- Continue to work with HP CSS operators in understanding the longer term effect of having bitumen emulsion trapped in the Colorado Group.