16 November 2011

Sent Via Email Only: Trevor.Dark@ercb.ca

Trevor Dark, COO
Energy Resources Conservation Board
Suite 1000, 250 – 5th Street SW
Calgary, AB T2P 0R4

Dear Mr. Dark,

RE: PLAINS MIDSTREAM CANADA NPS 20 RAINBOW PIPELINE
BOW TIE ANALYSIS AND POINT-BY-POINT COMPARISON OF OLD AND NEW RAINBOW NPS 20 PIPELINE
LEAK DETECTION AND PIPELINE RESTART PROCEDURES

Please find attached, the final *Bow Tie Analysis and Point-by-Point Comparison of Old and New Rainbow NPS 20 Pipeline Leak Detection and Pipeline Restart Procedures* report by Det Norske Veritas, as committed to in item #5 of Plains Midstream Canada, ULC's 31 October 2011 monthly update report no. 2.

Should you have any questions, please do not hesitate to contact the undersigned at (403) 450-1221.

Yours truly,
PLAINS MIDSTREAM CANADA ULC

Michelle Stepp
Regulatory Specialist

Encl.

DET NORSKE VERITAS

Bow Tie Analysis and Point-by-Point Comparison of Old and New Rainbow NPS 20 Pipeline Leak Detection and Pipeline Re-start Procedures

Plains Midstream Canada

Project No. PP016985
November 2011

Bow Tie Analysis and Point-by-Point Comparison of Old and New Rainbow NPS 20 Pipeline Leak Alarm Response Procedures	DNV Energy Suite 150, 2618 Hopewell Place NE Calgary, Alberta T1Y7J7 Canada Tel: (403) 250-9041 Fax: (403) 250-9141 http://www.dnv.com
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Executive Summary

As part of its ongoing support to assist Plains Midstream Canada (Plains) to gain Energy Resources Conservation Board (ERCB) approval to re-start the NPS20 Rainbow pipeline following a failure at MP 188 on April 28th, 2011, DNV conducted an engineering assessment (EA) which was delivered to Plains on July 27th, 2011. The issues of leak alarm response and pipeline re-start were addressed in Task 7 of the EA (section 10 of the report), in which DNV made the following near-term recommendation in section 10.6.1:

"The degree of improvement afforded by the "new" alarm response procedures [new after the spill] *relative to the "old" procedures* [in place at the time of the spill] *should be demonstrated by a "point-by-point" comparison of the old and new procedures, accompanied by a systematic assessment of the number and adequacy of the barriers to pipeline leaks that are provided by the two systems. An effective way to accomplish this would be to develop formal "Bow Tie" diagrams to graphically illustrate the number of barriers provided by the original and new procedures".*

In a letter dated August 4th, 2011, the ERCB wrote to Plains with a series of requests for information, an excerpt from one of which is shown below:

"*Plains must discuss and demonstrate the plan of action and schedule to implement the changes including establishment of continuous on-site supervisors in the control room as well as the implementation of the near-term recommendations identified in section 10.6.1 of the DNV report…"*

Plains responded to the ERCB on August 9th, 2011, an excerpt from which reads:

"Plains has undertaken to implement the control centre recommendations as outlined in the DNV report as quickly as possible, with most of the items to be completed by the end of September 2011".

On the above basis, Plains invited DNV to conduct the "point-by-point" comparison and the "Bow Tie" analysis, which was achieved via a series of workshops held between September 13th - 15th, 2011 at Plains Control Centre, located in Olds, Alberta.

Overall Conclusion

DNV's systematic review of Plains' enhancements to the Rainbow Pipeline leak detection and pipeline re-start procedures using "Bow Tie" analysis and "point-by-point" comparison has demonstrated that significant improvements have been made to both the leak detection and pipeline re-start procedures. The net result of these modifications should be a significant

decrease in the likelihood that control centre operators fail to take appropriate actions in the event of a further pipeline incident.

Whilst the old procedures contained information that was adequate to identify and control a pipeline leak event, the new procedures have significantly strengthened existing barriers and added additional barriers to prevent an incorrect response in relation to both leak detection and pipeline re-start.

Improvements to Leak Detection Procedures

Based on the comparison of the old and new leak detection procedures, significant strengthening of existing barriers to prevent an incorrect diagnosis have been noted with respect to the following 6 items:

1. **Training** – refresher training exercises have been held for all console operators following the MP 188 incident to reflect firstly the lessons learnt from the incident itself, and secondly the introduction of the new leak alarm response and pipeline re-start procedures. The training manual is being continuously updated.

2. **Clear, consistent information to support leak assessment** – Simsuite is now regarded as the primary source of information to determine if a pipeline imbalance or leak is suspected. The new procedure also emphasizes the importance of reviewing PLM and SCADA data in conjunction with prioritizing attention to leak triggers and Abnormal Operating Conditions (AOCs). The aim of this part of the new procedure is to avoid the console operator concentrating on solely one potential leak source without considering others.

3. **Leak diagnosis and response procedures** – these have been a major focal point of Plains' response to the MP 188 event. The leak detection procedure has been enhanced by:

    a) providing standardized leak detection procedures that are applicable to all consoles rather than only the pipeline specific procedures,

    b) including a specific leak trigger list to focus attention on all possible leak symptoms in the new procedures,

    c) clarification and amplification of the flow diagram to ensure that all potential leak symptoms are completely evaluated,

    d) stipulating specific time and flow volume criteria to determine the urgency of response (a console operator **must** raise the level to shift supervisor within a maximum of 1 hour of an "unexplained" alarm),

e) clearer definition of console operator and shift supervisor roles and responsibilities, and

e) making the leak detection procedure directly accessible on the SCADA displays as well as in the procedures manual.

4. **Active investigation of leak alarms** – this section of the new procedure requires operators to closely monitor alarms for a period of up to 2 hours following the declaration of the "All Clear" or "Return to Normal".

5. **Teamwork** – this section of the procedure establishes specific criteria for requesting assistance from supervisors, Plains management, and/or field personnel as prescribed in the flow diagram and text (see page 4 of the leak detection procedure). An unexplained alarm must be raised to at least Shift Supervisor level within a maximum time interval of 1 hour.

6. **Operator alertness** – the old procedure did not refer to operator alertness, but Plains has recognized an opportunity for improvement and will implement Plains All American Control Room Management processes for fatigue management. Revisions to the fatigue management program will be conducted in Q1 2012.

In addition, three additional barriers have been added with respect to leak alarm response:

1. **Systematic approach to alarm management** – this section of the procedure emphasizes the importance of the SimSuite alarms for leak diagnosis, and modifications are being made to the alarm management software that will integrate PLM and SimSuite alarms and adjust alarm set points so that they are appropriate for leak conditions. The new alarm management framework will be completed by the end of Q4 2011.

2. **Clear roles and responsibilities for console operators and supervisors** – the new procedure clearly defines the responsibility for supervisors to provide an independent but complementary perspective to the role of the console operator. The respective roles of the console operator and the shift supervisor are also clearly defined in an organization chart on page 3 of the procedure. The role of the shift supervisor is significantly amplified over and above the old procedure.

3. **New on-site 24/7 supervisory positions** – immediately following the MP 188 incident, Plains advised the ERCB that supervisory assistance would be available on site at all times. The recruitment process for the new supervisory positions is ongoing and will hopefully be complete in Q1 2012. In the interim period, supervisory coverage is provided by the Console Supervisor and/or the Control Centre Manager.

Improvements to Pipeline Re-start Procedures

The first major strengthening of the barriers to prevent an "incorrect" re-start is that a specific pipeline re-start procedure is now in place; previously, it was implicit at best within the general pipeline start up procedure.

The improvements relating to changes between the old and new procedures include the strengthening of a barrier which was in place prior to the event:

1. **Assessment of criteria for re-starting the pipeline following shutdown due to upset** - prior to the MP 188 incident, the old procedures provided little guidance regarding criteria for re-starting the pipeline; training was the primary vehicle for providing guidance for re-start following shutdown due to leak alarms or Abnormal Operating Conditions. The new procedures describe a formal process that requires personnel in addition to the console operator to be involved in the assessment of the leak situation and the decision to re-start the pipeline.

In addition to above, three new barriers have been added:

1. **Provide specific procedural guidance to support assessment of re-start following shutdown due to leak or Abnormal Operating Conditions** – the new re-start procedure has been added since the MP 188 incident. Although referring to pipeline start up (as opposed to re-start), the old procedure referred only to the console operator in relation to the involvement of Control Centre personnel. The new re-start procedure requires significantly more authorization (see below).

2. **Obtain authorization to re-start pipeline** – the new procedure includes a formal process to obtain approval to re-start the pipeline, and definition of the approvals that must be obtained. The new procedure specifically states that the Shift Supervisor **cannot** provide sole authorization for pipeline re-start. An initial "All Clear" is required from all personnel involved in the original event, after which written approval to re-start is required from at least two of PMC Operations/Integrity/Measurement/Control Centre or Senior Management. The verification of the written approval should be validated by the Control Centre Manager prior to re-start. The Control Centre management will remain present in the control centre during the re-start of the pipeline.

3. **Monitor pipeline for stability following re-start** – as specified in the re-start procedure, key pipeline parameters will be regularly monitored for at least 8 hours following the re-start to ensure that conditions are stable. This ensures that the console operator's attention is maintained on the affected pipeline segments.

Table of Contents

1 INTRODUCTION

As part of its ongoing support to assist Plains Midstream Canada (Plains) to gain Energy Resources Conservation Board (ERCB) approval to re-start the NPS 20 Rainbow pipeline following a failure at MP 188 on April 28th, 2011, DNV conducted[1] an engineering assessment (EA) which was delivered to Plains on July 27th, 2011. The issues of leak alarm response and pipeline re-start were addressed in Task 7 of the EA (Section 10 of the report), in which DNV made the following near-term recommendation in section 10.6.1:

"The degree of improvement afforded by the "new" alarm response procedures [new after the spill] *relative to the "old" procedures* [in place at the time of the spill] *should be demonstrated by a "point-by-point" comparison of the old and new procedures, accompanied by a systematic assessment of the number and adequacy of the barriers to pipeline leaks that are provided by the two systems. An effective way to accomplish this would be to develop formal "Bow Tie" diagrams to graphically illustrate the number of barriers provided by the original and new procedures".*

In a letter dated August 4th, 2011[2], the ERCB wrote to Plains with a series of requests for information, an excerpt from one of which is shown below:

"*Plains must discuss and demonstrate the plan of action and schedule to implement the changes including establishment of continuous on-site supervisors in the control room as well as the implementation of the near-term recommendations identified in section 10.6.1 of the DNV report…"*

Plains responded to the ERCB on August 9th, 2011[3], an excerpt from which reads:

"Plains has undertaken to implement the control centre recommendations as outlined in the DNV report as quickly as possible, with most of the items to be completed by the end of September 2011".

On the above basis, Plains invited DNV to conduct the "point-by-point" comparison and the "Bow Tie" analysis, which was achieved via a series of workshops held at Plains Control Centre, located in Olds, Alberta.

2 APPROACH

A total of three workshops were conducted at the Olds Operations Centre between September 13th-15th, 2011. The workshops were facilitated by Bill Nelson of DNV with support from Alasdair Clyne (also of DNV). Plains participants were Richard Miller, Control Centre Manager, and Wes Simpson, Control Centre Supervisor.

The first workshop session focused on a broad discussion of the objectives, critical functions, resources, and tasks associated with maintaining safe operations of the pipeline, i.e. correctly identifying the source of any alarms and taking the appropriate actions. This discussion helped establish the overall framework for the more detailed bow tie and point-by-point workshops.

The second workshop focused on the development of the bow tie diagram. The "Critical Event" was defined as "Control Centre operators fail to take appropriate actions following pipeline break." The bow tie diagram was then systematically developed to show the potential causes of the Critical Event and the barriers that are in place to prevent its occurrence. The barriers were colour coded to differentiate between:

i) barriers that were in place at the time of the MP 188 incident,

ii) barriers that have been strengthened since the incident, and

iii) new barriers that have been established by Plains since the occurrence of the incident.

The third workshop focused on the development of a spreadsheet summarizing the "point-by-point" comparison of the old leak detection and pipeline re-start procedures and the new procedures that are currently in effect. Columns were provided in the spreadsheet to denote:

i) the specific procedure attributes that were evaluated,

ii) an assessment of each attribute for the old procedures,

iii) an assessment of each attribute for the new procedures,

iv) a summary of the differences between the two, and

v) an assessment of the degree of improvement afforded by the new procedures.

Taken together, the complementary approaches of the bow tie analysis and the point-by-point comparison provide a comprehensive picture of the increased protection that has been accomplished through implementation of the new procedures and associated processes.

The bow tie and point-by-point comparison was made based on the following Plains' documents:

i) the old procedures; namely, Section VI "Line Balance" and Section VII "Mainline Emergency Shutdown" of the "Rainbow Pipeline Procedures for Pipeline Operations" manual[4], and

ii) the new procedures; namely, procedure 13.01 "Leak Detection Procedure"[5] and 13.02 "Pipeline Re-Start Procedure" [6].

3 BOW TIE ANALYSIS RESULTS

Bow tie diagrams were originally developed by the offshore oil and gas industry, and are used to clearly illustrate and communicate the barriers that can be used to prevent an accident or mitigate the consequences if the accident occurs.

Figure 1 shows the bow tie diagram that was developed to illustrate the barriers that are currently in place to prevent the "Critical Event"; namely "Control Centre operators fail to take appropriate actions following pipeline break." The yellow and black cross-hatched box at the top of the diagram is the hazard that will be released if the critical event occurs. The critical event is the orange circle at the center of the bow tie. The possible causes of the critical event are shown in the blue boxes at the left of the diagram. The boxes placed between each cause and the critical event are barriers that can prevent the critical event from occurring if that cause is present.

In the same manner, the red box at the right of the diagram represents potential consequences of the critical event. Since the focus of the new procedures is to prevent the occurrence of the critical event, the consequence side of the bow tie diagram has not been developed.

The barriers on the bow tie diagram are colour-coded as follows:

- **Grey** – Existing barriers that were in place at the time of the incident.
- **Black** – Existing barriers that have been strengthened by the enhancements Plains has implemented since the event.
- **Green** – New barriers that have been established as a result of the enhancements Plains has implemented.

The identification of "existing", "strengthened", and "new" barriers was based on the assessment of procedures and the associated systems and processes (e.g. training, displays, administrative controls, etc.) that were in place at the time of the MP 188 event compared with those currently in effect based on the enhancements implemented by Plains since the event. The bow tie workshops were group exercises to qualitatively evaluate the improvements based on the subject matter expertise represented by Plains and DNV participants.

As can be seen from the bow tie diagram, four different potential causes of the critical event were identified:

i) the operator fails to diagnose the leak and fails to shut the pipeline down,

ii) the operator re-starts the pipeline whilst the pipeline is still leaking product,

iii) the operator fails to act when a leak is suspected, and

iv) there is inadequate information to confirm that a leak has occurred.

Each of the above potential causes is considered below.

3.1 Operator Fails to Diagnose Leak and Shut Down Pipeline

This cause covers the situation where the operator fails to diagnose the leak and shut down the pipeline as required. Clearly, this situation occurred during the MP 188 incident.

As shown on the diagram, nine barriers (black and grey boxes) were in place at the time of the event. Six of these have been strengthened by Plains' modifications since the event:

1. **Training** – refresher training exercises have been held for all console operators following the MP 188 incident. These exercises reflected firstly the lessons learnt from the incident itself, and secondly the introduction of the new leak alarm response and pipeline re-start procedures. Continued emphasis was placed on the console operator's duty to shut the pipeline down when indications of a leak are present during personal visits to the Olds Control Centre by both the Plains Vice- President of Operations and the President. In addition, the training program is being modified to improve its structure (definition), administration (formalized record keeping, performance evaluation and testing, refresher training schedules) and depth (new procedures, increased reference material and topics). The Olds Control Centre training manual is currently being updated based on the Plains All American training manual. Some parts of the training manual have already been updated with new procedures, which include performance indicators to measure goals and objectives such as periodic training, refresher training and exercises for operator and supervisor proficiency in the use of SCADA/SimSuite/PLM.

   Finally, it is understood that Plains intends to conduct additional training exercises based on the controlled physical removal of product from the pipeline that will allow operators to practice leak diagnosis and the decision processes required to assess the situation and determine whether the pipeline should be shut down. The first physical removal exercise is scheduled for Q4 2011.

2. **Clear, consistent information to support leak assessment** – the "Leak Detection Overview" section of the Leak Detection procedure states that… "For pipeline segments configured with double redundant* leak detection systems, SimSuite will be the primary source of information to determine if a pipeline imbalance or leak is suspected. SimSuite shall be used in conjunction with other PLM and SCADA data". Therefore, Simsuite is regarded as the primary source of leak detection for the Rainbow pipeline system, but the importance of reviewing data from the SCADA system and PLM in conjunction with prioritizing attention to leak triggers and Abnormal Operating Conditions (AOCs) is clearly identified in the flow diagram in the Leak Detection procedure. The emphasis on integrating information from all data sources is to avoid the console operator concentrating on solely one potential leak source without considering others.

3. **Leak diagnosis and response procedures** – these have been a major focal point of Plains' response to the MP 188 event. The Leak Detection procedure has been enhanced by:

   a) providing standardized leak detection procedures that are applicable to all consoles. There was no formal "re-start" procedure before the MP 188 incident,

   b) in the new procedures, inclusion of a specific leak trigger list to focus attention on leak symptoms, the aim being to avoid an operator concentrating solely on one potential leak cause without considering other possibilities,

   c) clarification and amplification of the flow diagram to ensure that all potential leak symptoms are completely evaluated,

   d) specific time and flow volume criteria to determine the urgency of response. The old procedure included a flow chart whereby the console operator only had to notify a team lead/measurement advisor as much as 4-5 hours after detection of a negative imbalance on the SCADA system; the new procedure compels reporting of an "unexplained" alarm to a supervisor within a maximum of 1 hour, depending on the line flow rate,

   e) clear definition of console operator and supervisor roles and responsibilities for leak detection and response, and

* The double redundancy refers to Plains having three different display systems, namely SCADA, Simsuite and PLM. Some leak detection capacity will still be present even in the unlikely event that two of the three systems fail

f) making the leak detection procedure directly accessible on the SCADA displays as well as in the procedures manual.

4. **Active investigation of leak alarms** – this section of the procedure requires operators to closely monitor alarms for as long as 2 hours following the declaration of "All Clear" or "Return to Normal". In the event that the console operator verifies that an imbalance is explained and the "All Clear" is given, the segment must still be monitored for a period of up to 2 hours, depending on where in the procedure a return to normal operating conditions is identified (pages 4 and 5, procedure 13.01).

5. **Teamwork** – this section of the procedure establishes specific criteria for requesting assistance from supervisors, Plains management, and/or field personnel as prescribed in the flow diagram and text (see page 4 of the leak detection procedure). An unexplained alarm must be raised to at least Shift Supervisor level within a maximum time interval of 1 hour.

6. **Operator alertness** – the old procedure did not refer to operator alertness, but Plains has recognized an opportunity for improvement and will implement Plains All American Control Room Management processes for fatigue management. Revisions to the fatigue management program will be conducted in Q1, 2012.

In addition, three additional barriers have been added:

1. **Systematic approach to alarm management** – this section of the procedure emphasizes the importance of the SimSuite alarms for leak diagnosis, and modifications are being made to the alarm management software that will integrate PLM and SimSuite alarms and adjust alarm set points so that they are appropriate for leak conditions. The new alarm management framework will be completed by the end of Q4 2011.

2. **Clear roles and responsibilities for console operators and supervisors** – the new procedure clearly defines the responsibility for supervisors to provide an independent but complementary perspective to the role of the console operator. The respective roles of the console operator and the shift supervisor are also clearly defined in an organization chart on page 3 of the procedure. The role of the shift supervisor is significantly amplified over and above the old procedure.

3. **New on-site 24/7 supervisory positions** – immediately following the MP 188 incident, Plains advised the ERCB that supervisory assistance would be available on site at all times. The recruitment process for the new supervisory positions is ongoing and will hopefully be complete in Q1 2012. In the interim period,

supervisory coverage is provided by the Console Supervisor and/or the Control Centre Manager.

3.2 Operator Re-starts Pipeline During Actual Leak Situation

This cause covers the situation where the operator shuts down the pipeline but then re-starts it during an actual leak situation. This scenario occurred during the Rainbow Pipeline MP 188 incident.

One barrier was in place prior to the event, and this barrier has been strengthened:

1. **Assessment of criteria for re-starting pipeline following shutdown due to upset** – prior to the MP 188 incident, the old procedures provided little guidance regarding criteria for re-starting the pipeline; training was the primary vehicle for providing guidance for re-start following shutdown due to leak alarms or Abnormal Operating Conditions. The new procedures describe a formal process that requires personnel in addition to the console operator to be involved in the assessment of the leak situation and the decision to re-start the pipeline.

In addition, three new barriers have been added:

4. **Provide specific procedural guidance to support assessment of re-start following shutdown due to leak or Abnormal Operating Conditions** – the new re-start procedure has been added since the MP 188 incident. Although referring to pipeline start up (as opposed to re-start), the old procedure referred only to the console operator in relation to the involvement of Control Centre personnel. The new re-start procedure requires significantly more authorization (see below).

5. **Obtain authorization to re-start pipeline** – the new procedure includes a formal process to obtain approval to re-start the pipeline, and definition of the approvals that must be obtained. The new procedure specifically states (role description on page 3 of 8) that the Shift Supervisor **cannot** provide sole authorization for pipeline re-start. An initial "All Clear" is required from all personnel involved in the original event, after which written approval to re-start is required from at least two of PMC Operations/Integrity/Measurement/Control Centre or Senior Management. The verification of the written approval should be validated by the Control Centre Manager prior to re-start. The Control Centre management will remain present in the control centre during the re-start of the pipeline.

6. **Monitor pipeline for stability following re-start** – as specified in the re-start procedure (page 5 of 8 and the flow diagram), key pipeline parameters will be regularly monitored for at least 8 hours following the re-start to ensure that

conditions are stable. This ensures that the console operator's attention is maintained on the affected pipeline segments.

3.3 Failure to Act When Leak is Suspected

This cause covers the situation where the console operator suspects a leak but fails to act to shut down the pipeline.

Two barriers were in place prior to the event, and one of them has been strengthened:

- **Management support for conservative action** – since the MP 188 incident, regular communications have been provided by senior management of their support for conservative action (i.e. to shut down the pipeline) when a leak is suspected. Both the Operations Vice-President (Stephen Bart) and the Company President (Dave Duckett) have visited the control centre since the incident to emphasize the above.

In addition, one new barrier has been added:

- **Emphasize authority to shut down pipeline** – the new leak detection procedure clearly states (both in the flow diagram and the written text) that the console operator has the authority to shut down the pipeline if deemed appropriate.

3.4 Inadequate Information to Confirm Leak

This cause covers the situation where there is insufficient information to conclusively diagnose a leak situation. This primarily relates to the situation where the leak is so small that the indications may be inconclusive or transitory.

For this cause, four barriers were in place before the event, and one new barrier has been added:

- **New procedure provides assistance to confirm leak** - the new leak detection procedure provides assistance to confirm the presence of a leak by including specific instructions for evaluating and integrating information from all Simsuite and PLM alarms, together with SCADA parameters, to confirm whether a leak is present.

4 POINT-BY-POINT COMPARISON RESULTS

The bow tie analysis described in Section 3 provides a simple, visually-orientated manner of comparing those barriers in place to prevent a console operator taking incorrect action:

i) at the time of the MP 188 incident, and

ii) after incorporation of the new procedures.

The point-by-point assessment is a complementary method of comparison which looks directly at each element of the procedures in place at the time of the incident and those currently in place. Specifically, the assessment compared the procedures within Section VI "Line Balance" and Section VII "Mainline Emergency Shutdown" of Reference 4 (the old procedures) with procedures 13.01 "Leak Detection Procedure"[5] and 13.02 "Pipeline Re-Start Procedure"[6] (the new procedures).

Note: In the old procedures, the pipeline re-start procedure was written simply for starting up the pipeline for all conditions including normal start up. There was no specific procedure for re-start from upset conditions that would directly correspond to the new pipeline re-start procedure.

The results of the point-by-point comparison are summarized in Table 1, where it can be seen that a total of 22 procedural elements are compared. The columns in the table are as follows:

- **Procedure element** – Concise summary of each procedure attribute that was evaluated.
- **Old procedures** – Assessment of that attribute for the old procedures that were in effect at the time of the incident.
- **New procedures** – Assessment of that attribute for the new procedures that are currently in effect.
- **Difference** – Concise summary of the primary differences between the old and new procedures.
- **Degree of improvement** – Qualitative assessment (minor, moderate, or significant) of the degree of improvement afforded by the new procedures and associated processes. Notation is also made whether the change represents a new barrier or improvement to an existing barrier, with a reference to the specific barrier.

4.1 Summary of Findings of Point-by-Point Comparison

As can be seen Table 1, the new leak detection and re-start procedures represent a significant improvement for the prevention of another event leading to failure to control a pipeline leak. While the old procedures contained information that was adequate to identify and control a pipeline leak event, the new procedures have significantly strengthened the existing barriers and added additional barriers. These improvements have resulted from the following types of changes:

- Improved procedure organization that allows controllers to systematically evaluate potential leak situations and select the appropriate response.

- Clearer definition of critical parameters (e.g. leak triggers and Abnormal Operating Conditions – AOC's) that should be monitored to ensure that a leak alarm is properly diagnosed and correct and timely actions are taken. Monitoring of all the triggers and AOC's should assist in preventing inappropriate focus on suspected component or instrument failures.

- Emphasis that all three sources of leak alarm information (SCADA, PLM, and SimSuite) should be utilized in conjunction with each other to gather information to evaluate indications of a potential leak situation.

- Inclusion of criteria regarding time and flow volume to ensure that necessary actions are taken in time to prevent a significant spill in situations where a leak may be present.

- Clearer identification of the roles and responsibilities of console operators and shift supervisors.

- Clear definition of criteria for shutting down the pipeline when a leak is suspected.

- The requirement to obtain formal, written approval from at least two members of Senior Management (and validation from the Control Centre Manager) before re-starting the pipeline. This should prevent any future occurrence of a console operator re-starting the pipeline during a leak situation, as occurred during the MP 188 incident.

- The requirement for a console operator to contact a shift supervisor within a maximum of one hour following an "unexplained" alarm. This requirement now ensures that a console operator **cannot** act alone for an extended period following the occurrence of leak alarms without outside help, as occurred during the MP 188 incident.

- Clearer statement of the authority of controllers and supervisors to take conservative action to shut down the pipeline when indications of a leak are present. This has been backed up by visits to the Control Centre in Olds by both the Vice-President of Operations and the Plains President.

5 CONCLUDING COMMENTS

DNV's systematic review of Plains' enhancements to the Rainbow Pipeline leak detection and alarm response procedures using "bow tie" analysis (Figure 1) and "point-by-point" comparison (Table 1) has demonstrated that significant improvements have been made to both the leak detection response and the pipeline re-start procedures. The net result of these modifications should be a significant decrease in the likelihood that control centre operators fail to take appropriate actions following a pipeline break. In turn, this will result in the reduction of the consequences in the event of a further pipeline incident.

While the old procedures contained information that was adequate to identify and control a pipeline leak event, the new procedures have significantly strengthened existing barriers and added additional barriers.

6 REFERENCES

1. "NPS 20 Rainbow Pipeline Reinstatement Case Support", DNV report to Plains Midstream Canada, Rev. 0, July 27th 2011

2. "Det Norske Veritas Report and Plains Request to Resume Operation of NPS 20 Rainbow Pipeline" (License 5592-1), ERCB letter to Plains August 4th, author R. Graves

3. "Re: Response to the ERCB August 2011 Request for Information", S. Bart to Messrs. D. McFadyen and T. Dark, August 9th 2011

4. "Rainbow Pipeline Procedures for Pipeline Operations", Plains Midstream Canada Operations Department, May 2011

5. "Leak Detection Procedure", Document Number 13.01, Plains Midstream Canada Operational Department, Effective Date August 1st 2011

6. "Pipeline Re-Start Procedure", Document Number 13.02, Plains Midstream Canada Operational Department, Effective Date August 1st 2011

Table 1. Point-by-Point Comparison

Procedure Element	Old Procedures	New Procedures	Difference	Degree of Improvement
Summary of Tasks and Importance	A few "things to remember" are mentioned. Not updated to Plains Midstream Canada structure. Vague about situation description.	Introductory paragraph emphasizing complexity and significance of leak detection.	New introductory paragraph. Increased attention to SimSuite adds another level of confidence.	Significant - Improvement to existing barrier “Clear consistent information to support leak assessment.”
Roles and responsibilities	Procedure doesn't clearly describe who is responsible for doing what.	Organization chart, table of roles and responsibilities, emphasis on authority to shut down when in doubt.	Graphical representation of organization structure supplemented by descriptive representation of Roles and Responsibilities.	Significant - New barrier “Clear roles and responsibilities for console operators and supervisors”
Oversight role of shift supervisor	Not covered.	Clearly defines oversight role of shift supervisor.	The oversight role of the supervisor is now clearly defined.	Significant - New barrier “Clear roles and responsibilities for console operators and supervisors”
Staffing level	On call support.	Added 24/7 shift supervisor.	Supervisor available on site 24/7.	Significant - New barrier “New on-site 24/7 supervisory position”
Teamwork and task sharing among console operators and supervisors	Less emphasis on teamwork and it was left up to individual console operator discretion to call for help.	Criteria, timelines, flow rates, steps and actions are clearly laid out. Supervisor roles are laid out in separate roles and responsibilities document.	More clearly described.	Significant - Improvement to existing barrier “Teamwork.”
Authority to shut down pipeline	Mentioned but not emphasized.	Clearly communicated, emphasized, and supported by Senior Management.	Much greater coverage and emphasis.	Significant - New barrier “Emphasize authority to shut down pipeline”
Authority to re-start pipeline	No documented procedure for re-start from upset conditions.	Documented re-start procedure with clear criteria and requirements for approval. Also requirement for continued monitoring after re-start.	Addition of a critical barrier.	Significant - New barrier “Obtain permission to re-start pipeline.”

Table 1. Point-by-Point Comparison (Cont.)

Procedure Element	Old Procedures	New Procedures	Difference	Degree of Improvement
Conditions under which leak detection procedures implemented	"Mainline over and short" procedure title defines applicability.	Triggered after leak detection alarm or warning.	Different philosophy - initiated by upset.	Moderate - Improvement to existing barrier "Clear and consistent information to support leak assessment."
Clarification of actions required in response to alarms or warnings	Actions are mentioned but are vague and unorganized.	Defined by timeline, priority, and flow conditions.	Clear link between alarm and action.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."
Definition of critical parameters and importance of continual attention to them	Unclear.	Prominent focus on leak triggers and Abnormal Operating Conditions.	Clearly described and more granular.	Significant - Improvement to existing barrier "Clear consistent information to support leak assessment."
Accessibility of procedure	Binder on shelf.	Binder on console and electronic version on SCADA network and Plains corporate network.	Greater accessibility and tighter version control.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."
Integration of information from SCADA, PLM, SimSuite	SimSuite treated in separate procedure.	Instructions to get information from all three sources - SCADA, PLM, and SimSuite.	Direct instruction to combine information from all sources.	Significant - Improvement to existing barrier "Clear consistent information to support leak assessment.".
Decision criteria for shutdown and re-start	Unclear regarding conditions requiring action, no criteria are given for re-start from upset conditions. No instructions to check again or for continued monitoring.	More defined, step by step with clear branch points and criteria.	Provides clearer guidance for critical decisions.	Significant – New barrier "Provide specific procedural guidance to support assessment of re-start following shutdown due to leak or AOCs."

Table 1. Point-by-Point Comparison (Cont.)

Procedure Element	Old Procedures	New Procedures	Difference	Degree of Improvement
Accounting for possible instrumentation and component failures	Specific troubleshooting suggestions, which could lead to distraction from potential leak indications. Allows for working alone without assistance.	Clearer direction and focus with definite decision criteria. Troubleshooting approach designed for use on any system. Direction to call for assistance sooner in the process.	Focuses attention on specific actions based on specific decision criteria.	Significant - Improvement to existing barrier "Clear consistent information to support leak assessment."
Time response requirements	Process initiated after one hour of potential imbalance. Potential bias towards inaction.	Process initiated after first alarm or warning. Response times graded according to flow volume.	Action is taken with clearer criteria when compared to old procedure.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."
Description of Abnormal Operating Conditions	Not included or referenced in procedure, but available from other sources.	Included directly in procedure.	Placing AOCs in procedure requires attention during process.	Moderate - Improvement to existing barrier "Leak diagnosis and response procedures."
Methods for assessing seriousness of condition and urgency for action	Even under serious conditions action could be delayed for an extended period.	Attention to subsequent and supporting alarms leads to determination of significance of situation.	Focus on timely assessment and response.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."
Clarity of flow diagram	Order of items was not appropriate for effective investigation.	Clearer steps, more granular, better indications and priority for actions.	Focus on timely assessment and response.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."
Communication, notification, and approval requirements	Misleading guidance for notification. No approval required for re-start.	Clear instruction for timely notification and communication. Clear requirements for obtaining re-start approval.	Removes ambiguity regarding communication, notification, and approval for re-start.	Significant - Improvement to existing barrier "Assessment of criteria for re-starting pipeline following upset."
Expected outcomes resulting from actions	Unclear.	Decision criteria are based on yes/no evaluations of expected outcomes at each step of the process.	Clear description of branching criteria for outcomes at each step of the process.	Significant - Improvement to existing barrier "Leak diagnosis and response procedures."

Table 1. Point-by-Point Comparison (Cont.)

Procedure Element	Old Procedures	New Procedures	Difference	Degree of Improvement
Coordination with field personnel for local operations	Mentioned but not emphasized.	Procedure step specifically calls for coordination with field personnel and other departments.	Clarifies need for coordination.	Minor - Improvement to existing barrier “Leak diagnosis and response procedures.”
Training requirements	No specific requirement for signoff for training completion.	Training and signoff for completion are required.	Clear validation of training completion.	Moderate - Improvement to existing barrier “Training.”

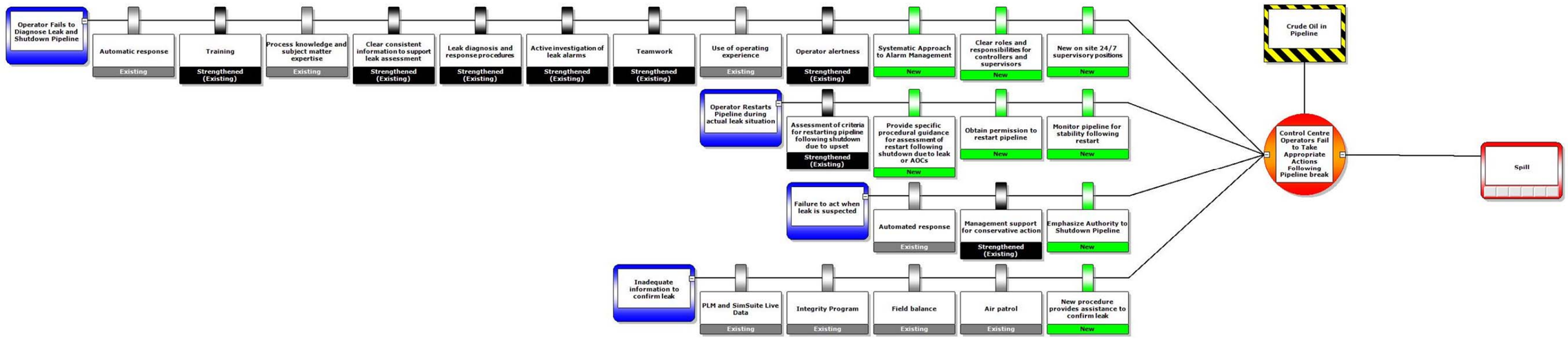

Figure 1. Bow Tie Diagram

DNV Energy

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