Pembina Pipeline Corporation Pipeline Failures Licence No. 2349, Line No. 10 July 20 and August 15, 2011

ERCB Investigation Report

February 26, 2013

Energy Resources Conservation Board

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ERCB Investigation Report: Pembina Pipeline Corporation, Pipeline Failures, July 20 and August 15, 2011

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1 Incident Description

First Failure (July 20, 2011)

At 7:02 a.m.[1] on July 20, 2011, the Pembina Pipeline Corporation (Pembina) contacted the ERCB St. Albert Field Centre (SAFC) to report a pipeline failure and a sweet crude oil release from the Moosehorn gathering pipeline in the Swan Hills area. The failure site (Legal Subdivision [LSD] 11, Section 7, Township 67, Range 9, West of the 5th Meridian) was about 7.5 kilometres north, northeast of the Swan Hills town site.

In the days leading up to the release, Pembina's Edmonton Control Centre (ECC) had been addressing various operating anomalies identified by Pembina's supervisory control and data acquisition (SCADA) system. These anomalies were initially triggered by the remnants of a nitrogen purge on July 9, 2011, on a segment of the pipeline that resulted in a measured segment volume imbalance. On July 19, 2011, at 7:42 a.m. the ECC foreman reviewed the 24-hour segment volume imbalance, and based on continuing segment volume imbalance, the foreman remotely shut down the pipeline. After the pipeline was shut down, Pembina began a field verification process. However, during the field verification process, the release location was identified by a third party (a Devon Canada Inc. [Devon] representative) at about 6:30 p.m. on July 19, 2011. Pembina reported the failure and the release location to the SAFC at 7:02 a.m. on July 20, 2011, almost 24 hours after Pembina shut down the pipeline and over 12 hours following identification of the failure location by Devon.

The SAFC designated this as a level-1 emergency using the ERCB Assessment Matrix for Classifying Incidents in ERCB *Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry*. On release notification, the SAFC activated an emergency operations centre (EOC) at the SAFC to coordinate the ERCB's response.

The failure resulted in crude oil migrating overland from the failure location down the pipeline right-of-way surface into a mixed forested area next to the right-of-way and into an unnamed but actively flowing creek. About 3.6 km of the creek and creek bank were affected by the release.

Once Pembina confirmed the failure, it activated its corporate emergency response plan (ERP), established a response operations centre, and dispatched emergency response equipment to the release site. On July 19, 2011, at about 8:00 p.m., Pembina installed a containment weir and built earthen berms to minimize any further environmental effects. To mitigate further seepage from the failed pipeline, Pembina started evacuating the crude oil from the pipeline on July 20, 2011, at 10:30 p.m. and seepage was stopped within 30 minutes.

Within about 48 hours from the discovery of the release, Pembina staff and third-party contractors established and executed containment and recovery operations that included a number of monitoring and control points (oil recovery and sampling locations) downstream

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[*] This report is accompanied by supporting documents. These documents are available from the webpage for this investigation report on the ERCB website, www.ercb.ca. For ease of reference, each document has been given a number, which is provided in a footnote when the document is cited (e.g., DOC01, DOC02, etc.).

[1] ERCB records indicate that the initial incident report was received at 7:02 a.m., while Pembina's records indicate 6:50 a.m. The ERCB will use its own time logs for this report.

of the initial creek entry. At 6:07 p.m. on July 24, 2011, the incident was called down[2] by the ERCB and the ERCB EOC ceased operations. Once the monitoring program was initiated, discussions were held with Alberta Environment (now Environment and Sustainable Resource Development [ESRD]) regarding the sampling and sample results throughout the incident; modifications were made as appropriate. As of the date of this report, monthly sampling of the creek water is being conducted by a Pembina contractor; no impacts have been reported to ESRD. An affected area where excavation activities occurred due to ineffective flushing operations has been backfilled and recontoured with the exception of a few localized areas. These areas will be risk managed in accordance with ESRD guidelines. Reclamation of the spill area, including the entry point to the creek, has been mostly completed. Erosion barriers, coconut matting,[3] and seeding with an approved seed mixture have taken place from the initial point of release up to and including the affected creek banks. Salvaged organic cover has been spread and seedlings have been planted on areas where steeper gradients could cause erosion and slope instability. Further remediation and monitoring will continue until the requirements of all other relevant regulatory agencies (ESRD and Environment Canada) are satisfied.

The incident occurred on Crown land in a rural wooded area with no residences. The SAFC did not receive any public complaints relating to the incidents. The failures did receive media attention, and both Pembina and the ERCB issued press releases relating to the incident.

Pembina initially estimated the release volume at about 200 cubic metres (m^3). After a more detailed evaluation, Pembina revised the release volume to between 130 m^3 to 160 m^3. Pembina removed the failed pipeline section and sent it to an independent third party, Det Norske Veritas (DNV), to complete a failure mechanism and metallurgical analysis. DNV prepared a report dated September 27, 2011[4] (first DNV report), which Pembina provided to the ERCB.

Second Failure (August 15, 2011)

At about 9:10 a.m. on August 15, 2011, Pembina reported a second pipeline failure about 1600 m from the location of the first failure. There is no way to determine the exact time the failure occurred as the second failure was identified while the pipeline was not operational and crews were at the first failure location. The second failure site was located at LSD 14-7-67-9W5M, near the top of a small high area within the segment that had previously been drained to allow the repair of the first failure to proceed. Therefore, the release was limited to a small volume of oil remaining in the pipeline at that location.

The second release affected an area of about 4 x 70 m on the pipeline right-of-way and did not migrate into the surrounding forest. Based on the size of the impacted area, the ERCB accepted Pembina's reported release volume of less than 1 m^3. Pembina's response and clean-up operations consisted of moving recovery equipment and crews from the first failure location to the second failure location when they became available.

[2] To downgrade an incident means to reduce the emergency level (e.g., from level-2 to level-1 or alert) based on the changing incident elements. To call down an incident means the emergency phase of the incident is over.

[3] Coconut matting consists of open weave, pure coconut mesh that offers durable surface erosion control. It is, therefore, recommended on sites where erosion forces are strong, climate is harsh, or plants are slow to establish.

[4] Det Norske Veritas, *Final Report – Metallurgical Analysis of Leak on the 8-Inch Diameter Moosehorn Oil Pipeline,* September 27, 2011 (DOC01).

Pembina removed the second failed pipeline section and also sent it to DNV for analysis. DNV prepared a report dated November 1, 2011[5] (second DNV report), which Pembina provided to the ERCB.

Pipeline History

The Moosehorn gathering pipeline, with an outside diameter of 219.1 millimetres (mm) (8 inches) and a wall thickness of 4.8 mm, is composed of carbon steel and externally coated with polyethylene tape and a fiberglass outer wrap. Pembina purchased this pipeline, originally licensed in 1962, from Federated Pipe Lines Ltd. in 2000.

The pipeline is part of the Pembina, Swan Hills gathering pipeline system, comprising 21 lateral gathering pipelines that transport sweet crude oil from various producing segments in the Swan Hills area.

2 Pembina's Pipeline Monitoring and Maintenance

Pembina has a pipeline integrity management program (IMP) that consists of a series of program manuals covering various aspects of pipeline integrity management. Collectively, these manuals assign responsibility and define the "who, what, where, when, why, and how" to manage pipeline integrity. Pembina has confirmed that the program manuals describe inspection, monitoring, and mitigation activities to address the threats to the long-term integrity of its pipelines. The program manuals address mechanical damage, mill defects, corrosion, stress corrosion cracking, coating damage, coating deterioration, unstable slopes, and the presence of low-frequency electric resistance welded pipe.

Pembina uses SCADA technology on all its pipeline systems, enabling continuous electronic monitoring and control of the pipeline systems from dedicated computer consoles located in the ECC. The systems are monitored 24 hours per day, 365 days per year. The SCADA system and associated leak detection software continuously monitor pipeline flow and operating conditions. When SCADA alarms are triggered, ECC operators and shift foremen implement prescribed protocol to investigate the alarm, and, initiate line shutdown procedures. Pembina routinely conducts leak tests whereby hydrocarbons are temporarily diverted away from the pipeline into tanker trucks to test the SCADA system and ECC operator performance. The last leak test occurred in September 2010, about one year prior to the first failure.

3 Root Cause Analysis

Pembina retained DNV to perform a metallurgical analysis on the failed pipe. The objectives of the analyses were to determine the metallurgical cause of the failures and identify any contributing factors. For both failures, the DNV analysis included

- magnetic particle inspection,
- examination and measurement of fracture surfaces of the cracks identified by the magnetic particle inspection, examination of some of the fracture surfaces under a

[5] Det Norske Veritas, *Final Report – Metallurgical Analysis of Leak on Eight-Inch Diameter Moosehorn Oil Pipeline*, November 1, 2011 (DOC02).

scanning electron microscope to document the fracture morphology and to determine if there was any evidence of in-service growth by fatigue, and

- mechanical testing and chemical analysis of the samples removed from the pipe.

Both DNV reports identified transgranular, circumferentially aligned stress corrosion cracking (C-SCC)[6] as the cause for pipe failure. The DNV reports concluded that the failures occurred at a colony of C-SCC. Several other C-SCC colonies were present on the pipe joints. There was no evidence of fatigue crack growth on the stress corrosion cracks.

The first DNV report concluded that the July 20 leak occurred at a colony of circumferentially oriented, outside-diameter, surface-breaking, interlinked stress corrosion cracks located across the longitudinal seam weld, which had a 10 o'clock orientation. Coinciding with this colony were circumferentially oriented, inside-diameter, surface-breaking cracks located at the seam weld. These inside-diameter cracks likely formed in the pipe mill from the trimming tool and are referred to as trimming cracks. The stress corrosion cracks propagated to one of these inside-diameter, surface-breaking cracks, resulting in the leak. The maximum depth of the stress corrosion crack at the failure site was 3.73 mm (78 per cent of nominal wall thickness). Through-wall length of the crack was 36 mm. Other crack colonies were present on the pipe near the 3 and 9 o'clock positions. Pembina noted some minor external corrosion defects on the joint of the failed pipe.

The second DNV report concluded that the August 15 leak occurred at a colony of circumferentially oriented, outside-diameter, surface-breaking, interlinked stress corrosion cracks located near the longitudinal seam weld, which had a 2 o'clock orientation. The stress corrosion cracks propagated nearly through wall, which lead to final failure by ductile overload. Inside-diameter, surface-breaking, mill-formed cracks that were present at the first failure were not present at the second failure. The maximum depth of the stress corrosion crack at the failure site was 4.8 mm (100 per cent of nominal wall thickness). The length of the crack that contained the failure was almost 70 mm. Several other crack colonies were present on the pipe joint. Most of the colonies were located between the 1:30 and 2:30 o'clock positions, with one colony located at about the 9:40 o'clock position.

Since the DNV reports concluded that the failure mechanism was the same in both failures and since Pembina has decided to replace the segment of pipeline containing the failed sections, Pembina did not perform a detailed root cause analysis for the second failure.

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[6] According to *Stress Corrosion Cracking, Recommended Practices, 2nd Edition,* published by the Canadian Energy Pipeline Association (*CEPA Recommended Practices*), transgranular stress corrosion cracking (SCC) on buried, high-pressure commodity pipelines occurs as a result of the interaction of susceptible metallic material, tensile stress, and an aggressive electrolyte. SCC initiates on the external pipeline surface and grows in both depth and surface directions. Growth along the surface is perpendicular to the principal stress, typically the hoop stress, resulting in crack alignment along the longitudinal axis of the pipeline (axially aligned SCC). Occasionally complex stresses occur, which may alter the direction of propagation from the longitudinal axis. SCC occurs beneath a mechanically failed coating and is capable of forming in the absence of general corrosion. Circumferentially oriented SCC (C-SCC) is a subset of transgranular SCC where the principle stress acting on the crack is a bending stress, which is typically acting in a longitudinal direction. The bending stress may be due to differential settlement of the backfill beneath the pipe, geotechnical ground movement, or possibly external loads other than soil.

According to information provided by Pembina, both failures occurred in pipeline segments located on an unstable slope that has been actively monitored since 1989 using slope movement indicators to characterize and track ground movement. During that time, 33 geotechnical inspections of this slope have been conducted, with the last one completed by Pembina on August 15, 2011.

Based on a review of the *CEPA Recommended Practices*, the two DNV reports, and information submitted by Pembina, the ERCB accepts the analyses in the DNV reports concluding that the failures occurred due to C-SCC.

4 Investigation Findings

The ERCB has carefully reviewed Pembina's Defect Assessment and Repair Manual (manual) and has concluded that Pembina maintains well documented procedures to assess and repair defects with the exception of specific methods to address occurrence of C-SCC. The manual generally addresses SCC, but does not show specific regard for C-SCC.

CEPA Recommended Practices states that C-SCC initiates and grows under conditions of high axial stress generated by slow soil movement (slope creep) and/or localized pipe bending in the vicinity of rocks and dents. *CEPA Recommended Practices* further states that failure criteria and life predictions require calculations or estimates of axial stresses and that repairing C-SCC by buffing removal and reinforcement is not recommended for C-SCC defects unless the source of the bending stress is positively identified and removed. Although Pembina states that its SCC evaluations follow *CEPA Recommended Practices*, the manual does not specifically refer to the constraints identified in *CEPA Recommended Practices* for C-SCC. As such, ERCB staff found that the manual does not adequately address or outline the steps to identify and correct issues related to C-SCC.

Pembina advised the ERCB that it considered the pipeline to be at low risk for axially aligned SCC, but at higher risk for C-SCC due to slope movement along the pipeline. To inspect for SCC, Pembina conducts magnetic particle inspections at all excavations associated with pipelines that have undergone an in-line inspection (ILI) where an anomaly has been identified requiring an integrity dig. Pembina conducts an ILI every five years based on the growth rate for its external metal loss features. It completed the last ILI on this pipeline in 2010, with 44 anomalies identified and excavated. Pembina did not find any SCC during the last ILI. Since 2000, only one integrity dig, conducted in 2007, showed SCC, which was identified as C-SCC. As a result of this finding, Pembina replaced 129 m of pipeline on the north slope of the Moosehorn River. Pembina did not provide any information that would indicate that it conducted any integrity digs near the locations of the failures that form the subject of this report.

Information provided by Pembina shows its efforts to monitor and mitigate slope instability and to inspect for SCC at integrity dig sites. Pembina's IMP includes monitoring and mitigating unstable slopes, which may include replacing or reinstalling the pipe by horizontal drilling, exposing the pipe to relieve stress, or exposing and recoating the pipe since improperly taped or disbonded coatings contribute to SCC. Pembina has identified 12 slopes with a greater likelihood of slope instability in the area surrounding the Swan Hills laterals and another four slopes within the Swan Hills region. At one of the slopes, geotechnical investigations have been conducted as many as 39 times since 1988. Of the 16 slopes with a greater likelihood of slope instability, during the last eight years Pembina has excavated the pipe to relieve pipe stress at three locations and replaced pipe at four other locations. In addition, it completed two digs on one slope totalling 3.5 m in length and conducted direct assessment digs on three slopes. Pembina did not conduct integrity digs or direct assessment digs on the remaining slopes, including the slope where the two failures that form the subject of this report occurred.

In November 2011, following the failures, Pembina developed a direct assessment dig program for C-SCC. While the program follows *CEPA Recommended Practices*, it will not be executed since Pembina does not plan to return the pipe to service and plans to completely replace the existing pipeline on the slope where the failures occurred.

Even though Pembina has conducted some integrity and direct assessment digs, it has not demonstrated targeted digs for C-SCC. It is also not clear if Pembina intends to apply the direct assessment dig program for C-SCC developed in November 2011 to the remaining pipelines located on other slopes.

Prior to the failures, Pembina's approach to C-SCC was to look for SCC at locations along the pipeline where ILI findings had identified pipeline segments with features such as external corrosion, requiring an integrity dig. However, C-SCC may not be associated with significant external corrosion and *CEPA Recommended Practices* states that significant coating damage may not be a prerequisite for C-SCC as cracking can follow the helix of the tape overlap and other minimal coating damage. This is supported by both DNV reports, which identified additional C-SCC near the failure locations, but did not identify any areas of significant external corrosion notwithstanding Pembina's evaluation of the first failure, which found the coating to be in generally poor condition. Due to the coating condition and C-SCC, Pembina cut out and replaced a total of five pipe joints adjacent to the location of the first failure. ERCB staff believe that Pembina's focus on ILI findings may have resulted in insufficient attention being paid to those portions of its pipeline that were susceptible to C-SCC but may not have been associated with integrity threats identified by an ILI.

The causes of C-SCC are well understood and documented. Pembina was aware that its pipeline was susceptible to C-SCC, had identified areas of high geotechnical ground movement, and had taken steps to monitor and mitigate slope instability. Prior to the failures, however, Pembina did not implement a specific program or procedure to identify and mitigate C-SCC on its pipeline in all areas of slope instability. Therefore, ERCB staff have concluded that Pembina did not take effective steps to implement and maintain a program specifically to identify and address C-SCC on its pipeline in areas of slope instability.

Pembina followed its protocol to respond to indications of a pipeline failure. After a pipeline shutdown due to an imbalance indication, the protocol permits restart of the pipeline by the ECC operator after consultation with the appropriate senior field operations personnel.

While addressing operating anomalies on July 15, 2011, about four days before identifying the first failure, Pembina conducted a stand-up pressure test on the five operating laterals. Pembina installed manual pressure gauges and monitored pressures from the ECC. The pressures were monitored for at least 1.5 hours and did not indicate anything unusual. However, after reviewing the incident, Pembina has realized the need for a consistent field process for completing such a test and for recording the data to reliably determine pipeline integrity.

On the morning of July 19, 2011, the ECC foreman reviewed the 24-hour segment imbalance as identified by SCADA. Based on the indications, the ECC shut down the pipeline. Once the pipeline was shut down, Pembina followed the protocol and the ECC operator e-mailed the ECC supervisor and the district manager to advise that the pipeline segment was shut down due to segment imbalance concerns. The district manager, in turn, notified the Swan Hills field operators; however, the designated field operator did not review the e-mail in a timely manner due to sudden illness. As a result, no follow-up occurred and Pembina did not restart the pipeline after the shutdown in the morning of July 19, 2011. Pembina had no protocol to confirm that there was follow-up by field operations, which prevented Pembina from discovering the failure prior to the third-party notification. Pembina did not determine the first failure location, nor did it take action to contain the first release until another party notified it of the failure location. ERCB staff concluded that Pembina's ECC had an inadequate protocol to properly identify and respond to the SCADA indication of a pipeline failure. ERCB staff have also concluded that Pembina did not maintain a clear protocol outlining the actions to take once the pipeline was shut down and the actions to follow before permitting any shutdown segment of the pipeline to resume operations.

After both failures, Pembina reviewed and updated its protocol and its field operations process to ensure that any pipeline showing a volume imbalance is adequately checked and inspected prior to restart. The ERCB is satisfied that, if there were a similar failure, the updates to Pembina's field operations process would result in Pembina staff taking immediate and adequate steps to confirm that a release had occurred and its location.

Pembina has also incorporated geotechnical baseline data in the ECC computer consoles to show pipeline segments that have higher geotechnical risk. Under the current revised protocol, the ECC supervisory staff must receive approval from Pembina management to restart a pipeline after a shutdown due to an imbalance indication. Additionally, Pembina requires positive confirmation by phone that field operations personnel have received the relevant shutdown notification.

Pembina neglected to inform the ERCB about the first release for almost 12 hours. As a result, Pembina failed to comply with Section 35(1) of the *Pipeline Act* for which the ERCB issued a High Risk Enforcement Action on October 28, 2011, in accordance with *Directive 019: Compliance Assurance*. On January 19, 2012, the ERCB accepted Pembina's response to the enforcement action.

Pembina took appropriate actions once external notifications had been completed. Pembina complied with the ERCB's criteria for containment and recovery of free produced fluids.

5 Post-Incident Assessment

The ERCB conducted a post-incident assessment for both failures on October 11, 2011, to review the actions taken by the ERCB and Pembina. The post-incident assessment determined that, with the exception of Pembina's failure to properly notify the ERCB of the first failure following identification of its location, Pembina's response to both incidents was well coordinated. ERCB staff identified one minor area for improvement. Specifically, the ERCB requires Pembina to review its procedures to ensure the timely activation of its liaison officer position when using the incident command system during an incident.

6 ERCB-Directed Actions

1) The ERCB directs that Pembina develop and implement a direct assessment dig program for C-SCC to inspect for, identify, and address potential C-SCC in all pipelines that may experience geotechnical conditions similar to those in which the two failures occurred.

2) In addition, the ERCB directs Pembina to share the knowledge that it has gained from these incidents with its industry peers so that they can take appropriate action to determine if any similar problems exist on their operating pipelines.

7 ERCB Follow-up

The ERCB Field Incident Response Support Team will follow up with Pembina within 30 days of issuance of this report regarding the area for improvement identified in the post-incident assessment.

The SAFC will follow up with Pembina on directed-action item no. 2 in Section 6 above within 90 days of issuance of this report.

The ERCB Technical Operations Group, Pipeline Operations Section, will also follow up with Pembina within 180 days of issuance of this report to confirm that Pembina has

- developed, implemented, and communicated the necessary improvements to its IMP and manuals to increase its focus on C-SCC in its operating pipelines;
- developed, implemented, and communicated the necessary changes to its ECC protocol and field operations process to identify and respond to leak indications; and
- completed the directed-action item no. 1 in Section 6 above to the satisfaction of the ERCB.