Trans Mountain Expansion Pipeline

Pipeline Reactivation

NPS 24 Hinton to Hargreaves and NPS 24 Darfield to Black Pines

Engineering Assessment

Updated

August, 2014

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1.0 REVISIONS AND UPDATES

A preliminary engineering assessment was included in the Trans Mountain Expasion Project application in Section 3.6 of Volume 4a – Project Design & Execution - Engineering. As part of the commitments included in the application, Trans Mountain committed to provide an updated engineering assessment upon completion of a risk assessment. In Trans Mountain's response to the National Energy Board IR 1.86 c, Trans Mountain indicated that current in-line inspection data was essential for the completion of a quantitative estimation of failure likelihood in a risk assessment. As an alternative, Trans Mountain completed a threat-based assessment. The results of the threat-based assessment have been incorporated into the engineering assessment as described in this document.

The engineering assessment has also been updated to incorporate any changes or errata that have been noted from the TMEP application document.

Table 1.1 has been provided below to allow a quick reference to those sections of the engineering assessment that have been added, modified or updated.

Table 1.1 – Revisions to the Original Engineering Assessment

Section	Revision
1.0	Added section 1.0 - Revisions and Updates
4.3	Original Table 3.6.1 – Pipe Manufacturers – Hinton to Hargreaves. Table included both the Hinton to Hargreaves and Darfield to Black Pines but the table was identified as only the Hinton to Hargreaves section. The table has been split to show both the Hinton to Hargreaves and Darfield to Black Pines sections of pipeline. The new tables are Table 4.3.1 – Pipe Manufacturers Hinton to Hargreaves and Table 4.3.1 – Pipe Manufacturers Darfield to Black Pines.
4.5	Text was revised to correct the hydrostatic test history for the 1965 hydrostatic test and to include the cause of the test failures associated with the 1965 hydrostatic test.
4.5	Original Figure 3.6.1 Hydrostatic Test History – Hinton to Hargreaves. The figure incorrectly showed a 100% SMYS hydrostatic tests for the 1964-1965 tests. The errata was corrected in the Trans Mountain response to the NEB IR. The corrected figure is included in this engineering assessment as Figure 4.5.1 Hydrostatic Test History – Hinton to Hargreaves. The revised figure also includes the highest pressure aschieved at the low point of the test sections.
4.7.1	External Corrosion. Originally included as section 3.6.3.7.1 in volume 4a of the application. The section was updated to include current information on cathodic protection and to add information from the threat-based assessment for above ground piping and casings.
4.7.2	Internal Corrosion. Originally included as section 3.6.3.7.2 in volume 4a of the application. The section was updated to include current information from the threat-based assessment.

Section	Revision
4.11	The Natural Hazards section has been updated to include current information and to include additional Natural Hazards mitigation sites identified as a result of the 2013 Natural Hazards Program. Original Table 3.6.4 has been updated and is now listed as Table 4.11.1 – Natural Hazards Mitigation Priority List (Hinton to Hargreaves).
4.12	Other Threats. Added this section to include other threats identified in the threat-based assessment.
Appendix A	Threat-Based Assessment. The Threat-Based Assessment document has been included as Appendix A.

2.0 REACTIVATION OF NPS 24 SEGMENTS (HINTON TO HARGREAVES AND DARFIELD TO BLACK PINES)

2.1 Background

Trans Mountain plans to reactivate two deactivated segments of the existing NPS 24 pipeline as part of TMEP. Reactivation will be undertaken in accordance with the NEB OPR and CSA Z662, Oil and Gas Pipeline Systems. The segments proposed for reactivation are:

- Hinton, AB to Hargreaves, BC – approximately 150 km in length, which was in continuous operation from 1953 to 2008; and
- Darfield, BC to Black Pines, BC – approximately 43 km in length, which was in continuous operation from 1953 to 2004.

2.1.1 Hinton to Hargreaves

The Hinton to Hargreaves segment was deactivated in 2008 under NEB Certificate OC-49 following completion of the TMX Anchor Loop Expansion Project (TMX-Anchor Loop). In anticipation of future growth, measures were taken to promote the long-term integrity of the deactivated segment to maintain the potential for its future reactivation.

2.1.2 Darfield to Black Pines

The Darfield to Black Pines NPS 24 pipeline segment was deactivated in 2004 under NEB Order XO-T099-05-2004 when the parallel NPS 30 segment was reactivated as part of the Capacity Upgrade Project. In anticipation of future growth, measures were taken to promote the long-term integrity of the deactivated segment to maintain the potential for its future reactivation.

The measures taken to ensure the long-term integrity of the deactivated pipeline segments included:

- removing the oil through the use of bi-directional pigs and a nitrogen purge;
- isolating the pipeline through the installation of weld caps;

- maintaining nitrogen in the pipeline (verified by pressure monitoring) to prevent internal corrosion;
- maintaining the cathodic protection (CP) system to prevent external corrosion:
- maintaining the Pipeline Protection Management System which includes One-Call and aerial patrol; and
- implementing the Trans Mountain Natural Hazards Program.

2.2 Regulatory Requirement

A preliminary engineering assessment has been completed as a first step in satisfying the requirements of the *OPR* for reactivation. The assessment details "the measures to be employed for the reactivation" and satisfies the intent of CSA Z662, Section 10.15.2 to "conduct an engineering assessment" and if the engineering assessment finds that the pipe is not suitable for service, to detail "the corrective measures necessary to make it suitable before reactivating." The preliminary engineering assessment will be updated to a final engineering assessment during the detailed engineering and design phase.

3.0 THREAT-BASED ASSESSMENT

As part of the original engineering assessment, Trans Mountain committed to underdake a risk assessment for the reactivation segments and to provide an updated engineering assessment upon completion of the risk assessment. Trans Mountain also committed to complete in-line inspections of the reactivation segments using high resolution metal loss, high resolution axial flaw detection and high resolution geometry inspection tools. Tool runs are planned to be completed in 2016.

Recognizing that the in-line inspections are essential to a quantitative estimation of failure likelihood, and in the absence of such current information at this time, Trans Mountain decided not to undertake a quantitative estimate of failure likelihood, but to complete a threat-based assessment.

Trans Mountain has completed the threat-based assessment and has included the threat-based assessment results in Appendix A – Threat-Based Assessment. Trans Mountain has also updated the engineering assessment for the reactivation sections to include additional findings or threats as identified in the threat-based assessment.

4.0 ENGINEERING ASSESSMENT

4.1 Objective

The purpose of the preliminary engineering assessment is to document the integrity management status of the segments to be reactivated and the measures that Trans Mountain will employ to verify their integrity prior to reactivation.

4.2 Scope

The preliminary engineering assessment examines the integrity history and condition of the deactivated pipeline segments and identifies the measures required to ensure fitness for service. The general approach to reactivation includes inspection, repair, and hydrostatic testing, similar to the approach that was employed for the reactivation of the NPS 30 Darfield to Kamloops segment in 2004. Elements of the preliminary engineering assessment are discussed in the following sections.

4.3 Pipe Description

Construction of the NPS 24 pipeline was completed in 1953 using double submerged arc welded pipe manufactured by Kaiser Steel Corporation and Consolidated Western Steel and flash welded pipe manufactured by A.O. Smith. The pipeline was coated in the field with coal tar enamel. A breakdown of the pipe manufacturers for the deactivated segments is provided in the Tables 4.6.1 and 4.6.2.

TABLE 4.3.1

PIPE MANUFACTURERS – HINTON TO HARGREAVES

Hinton to Hargreaves							
Manufacturer	**NPS**	**Specification**	**Grade**	**W.T. (mm)**	**Year**	**Seam Type**	**km of Pipe**
A.O. Smith	24	API 5L	290	12.7	1953	FW	2.1
A.O. Smith	24	API 5L	359	7.9	1953	FW	20.1
Consolidated Western Steel	24	API 5L	318	12.7	1953	DSAW	0.2
Consolidated Western Steel	24	API 5L	359	7.9	1953	DSAW	102.0
Kaiser Steel Corp.	24	API 5L	318	12.7	1953	DSAW	0.9
Kaiser Steel Corp.	24	API 5L	359	7.9	1953	DSAW	17.8
Kaiser Steel Corp.	24	API 5L	359	6.4	1953	DSAW	7.6

TABLE 4.3.2

PIPE MANUFACTURERS – DARFIELD TO BLACK PINES

Darfield to Black Pines							
Manufacturer	**NPS**	**Specification**	**Grade**	**W.T. (mm)**	**Year**	**Seam Type**	**km of Pipe**
Consolidated Western Steel	24	API 5L	359	7.9	1953	DSAW	33.8
Consolidated Western Steel	24	API 5L	359	8.7	1953	DSAW	3.6
Kaiser Steel Corp.	24	API 5L	359	7.9	1953	DSAW	5.5

4.4 Service

Upon completion of TMEP, the reactivated segments will form part of Line 1. The products transported will be similar to those which are currently transported in the TMPL system with the exception that very little heavy crude will be transported. Heavy crude will be largely transported in Line 2. The reactivated segments are expected to operate at pressures that are consistent with historical operating pressures and flow rates.

4.5 Hydrostatic Testing

The initial post-construction hydrostatic test for the Hinton to Hargreaves segment took place in 1953 (Figure 4.5.1). This segment was initially tested in three sections. The test pressures ranged from 83 to 91.5 per cent of the SMYS at the low points. No failures occurred as a result of these initial tests. Additional hydrostatic testing of the pipeline occurred in eight sections between 1964 through 1998 with a test pressure ranging between 88 and 101.8 per cent of the SMYS. Three failures occurred in the 1965 hydrostatic test. The 1965 hydrostatic test was ultimately abandoned and the pipe section was retested between 1973 and 1984. The cause of the test failures were determined to be due to gouges in the pipe body that occurred during original construction. No failures occurred in the other hydrostatic tests.

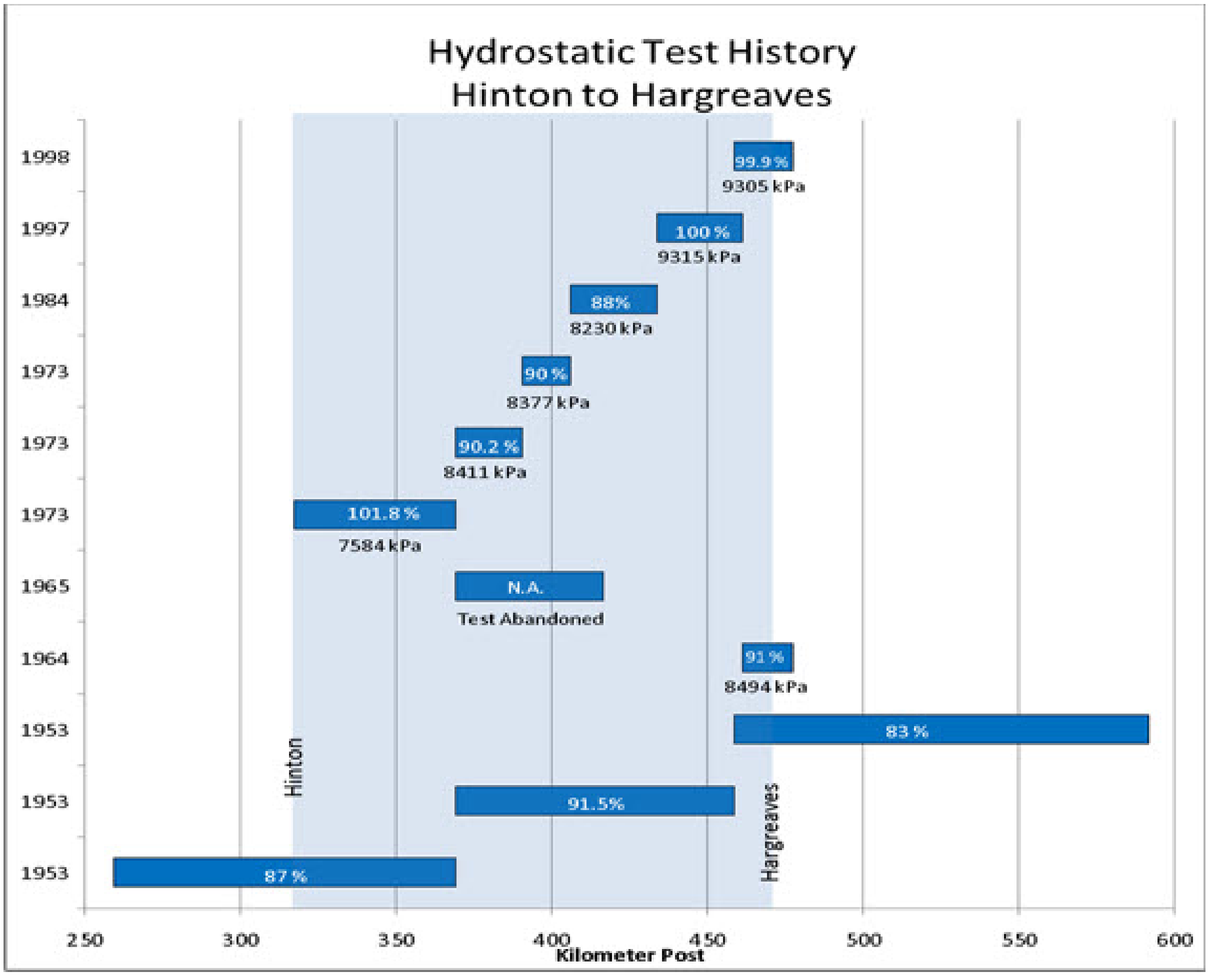

Figure 4.5.1 Hydrostatic Test History – Hinton to Hargreaves

The initial post-construction hydrostatic test for the Darfield to Black Pines segment took place in 1953 (see Figure 4.5.2). The pipeline was initially tested in one section. The test pressure was 83 per cent of the SMYS at the low point. The segment was retested in two sections in 1978. The test pressure achieved was 100 per cent of the SMYS at the low point of the two test sections. No failures occurred in either of the test sections.

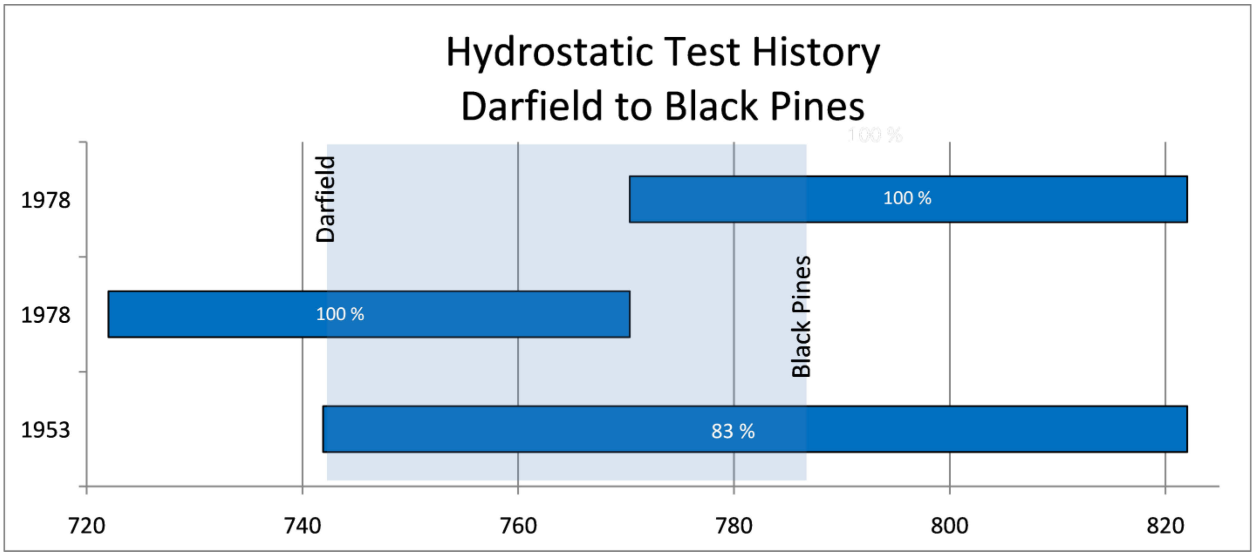

Figure 4.5.2 Hydrostatic Test History – Darfield to Black Pines

4.6 In-line Inspection

In-line Inspection (ILI) programs began on the TMPL system in the 1970s when ILI tools first became available. High resolution ILI tools became available in the 1990s. Since then, Trans Mountain has been inspecting the pipeline system using high resolution tools.

The Hinton to Hargreaves segment has been inspected with the following high resolution ILI tools:

- 1998 – Pipetronix WM Ultrasonic Metal Loss;
- 2001 – BJ GEOPIG (High Resolution Geometry);
- 2007 – BJ Vectra (High Resolution Metal Loss); and
- 2007 – GE UltraScan Crack Detection (USCD) (High Resolution Crack Detection).

The Darfield to Black Pines segment has been inspected with the following ILI tools:

- 1995 – Tuboscope MFL Metal Loss (Low Resolution Metal Loss); and
- 2003 – BJ GEOPIG (High Resolution Geometry).

Results of the ILIs are discussed in the following sections.

Prior to hydrostatic testing, Trans Mountain will complete ILIs of the deactivated segments using a high resolution metal loss tool, a high resolution axial flaw detection tool, and a high resolution geometry tool. These inspections will be completed by pushing the tools through the deactivated segments using nitrogen or compressed air. The tool configurations and methods of moving the tools will be determined during the detailed engineering and design phase.

Trans Mountain will also inspect the reactivated segments, within the first two years of operation, with a specialized high-resolution ultrasonic tool, to verify that no detrimental crack defects remain in the pipeline following hydrostatic testing. Ultrasonic tools require the pipe to be liquid filled and cannot be run prior to reactivation.

4.7 Corrosion

The NPS 24 mainline, including the active segments and the currently inactive segments, has a very good performance history with respect to corrosion defects. To date there have been no documented spills that have been attributed to internal or external corrosion.

The good performance of the mainline can be attributed to good adhesion of the coal tar enamel coating, maintenance, monitoring and upgrading of the CP system, turbulent flow rates in the pipeline and regularly scheduled cleaning pig runs (that minimize the likelihood of water and sediment gathering on the internal surface of the pipe), and a batch lineup that includes products such as gasoline (which assist in keeping the inside of the pipe clean).

In addition, the deactivated sections were filled with nitrogen to provide an inert atmosphere.

4.7.1 External Corrosion

Following the 1998 Pipetronix and the 2001 GEOPIG ILIs, 179 pipeline excavations were completed along the Hinton to Hargreaves section of pipeline. Ninety-four per cent of the excavations indicated that the adhesion of the coating was good.

CP has been maintained since the pipeline segments were deactivated. To maintain effective CP of the pipeline system, Trans Mountain targets a minimum value of -850 mV off-potential. This is consistent with the National Association of Corrosion Engineers (NACE) recommended practices for protection of pipelines from external corrosion and with Canadian Energy Pipeline Association published recommendations for protection of the pipeline from initiation and growth of stress corrosion cracking.

Off-potentials along the Hinton to Hargreaves segments are generally good with test station readings showing that the minimum target of -850 mV is being maintained with the exception of a few locations. Test station readings in 2012 showed that low readings occurred between KP 370 and KP 380, between KP 407 and KP 408, and between KP 455 and KP 465. A subsequent depolarization survey indicated that all locations meet the minimum 100mV shift criterion except for an area at KP 464.7. Engineering is currently under way to determine a mitigation solution. The 2012 annual test lead survey on the Darfield to Black Pines segment indicated no low readings.

There are no known interference issues on the reactivation segments. There are common bond points with the Trans Mountain loop lines and the ATCO gas line from Hinton to Jasper on the reactivation segments. No other stray currents have been identified.

The 2007 BJ MFL ILI indicated that there were five joints of pipe that had anomalies and clusters that were predicted to have a rupture pressure of less than 1.0. A rupture pressure ratio of 1.0 is the pressure at which the pipeline would be expected to fail at its SMYS. The inspection tool also identified 11 pipe joints that had external anomalies predicted to be deeper than 50 per cent of the pipe wall thickness. Some of these features are located within the anomalies and clusters that were reported to have a rupture pressure ratio of less than 1.0.

No excavations have been completed to further assess these anomalies as the segment was deactivated shortly after the inspection was completed. Prior to reactivation, a high resolution MFL metal loss ILI tool will be run and repairs will be completed to remove anomalies that would otherwise have the potential to fail during hydrostatic testing.

Off-potentials on the Darfield to Black Pines segment are good, with all test station readings showing that the minimum target of -850 mV is being maintained. No high resolution metal loss ILIs have been completed on this segment. Prior to reactivation, a high resolution MFL metal loss ILI tool will be run and repairs will be completed to remove anomalies that would otherwise have the potential to fail during hydrostatic testing.

4.7.1.1 Above Ground Pipe

Above-ground piping is susceptible to external corrosion due to factors such as aeration cells at the above / below ground interface, coating degradation, and lack of cathodic protection.The threat assessment identified two areas of above ground pipe in the reactivation sections that needed to be included in the engineering assessment.

The pipeline crosses Highway 16 through two pre-fabricated concrete tunnels at KP 459.5 (Overlander East) and KP 460.1 (Overlander West). The tunnels are approx. 46m long and 1.2m wide. Inside the tunnels the pipe is resting on sand beds. The top side of the pipe is exposed inside the tunnel and the pipe is buried at the tunnel exit.

The pipeline also contains an aerial span (the Overlander Aerial span) between Hinton to Hargreaves at KP 460.25. The pipeline at this location has a paint coating and crosses a steep ravine. The aerial span is approx. 37m long, with a height approximately 10m above the bottom of the ravine. Two A-frame supports are present at the crest of each side of the ravine. A visual inspection of the structure and midspan piers were completed in 2011. It was determined that overall the condition of the structure was good and that the coating was intact for the majority of the structure. Some spots were identified that require coating repair.

In addition to the proposed in-line inspections, KMC has committed to complete the following:

- A visual inspection on the air/soil transition regions and pipe supports for the transition sections to above ground pipe will be completed prior to reactivation on the Overlander Tunnels and Overlander Aerial span. Any coating deficiencies will be addressed.

4.7.1.2 Casings

There are currently 22 casings on the Hinton to Hargreaves reactivation pipeline segment. Four (4) are currently considered to be electrically shorted to the pipeline and three (3) are eloctrolytically shorted.

There are currently 3 casings on the Darfield to Black Pines reactivation pipeline segment. None of the casings are shorted to the pipeline.

All casings on the reactivation pipeline sections will be addressed in accordance with the Casing Remediation Program. The purpose of the Casing Remediation Program is to:

- Maintain system integrity and reliability
- Maintain regulatory compliance (i.e., provide adequate cathodic protection to the pipeline system).

The casing at the railway crossing at KP 339.4 was remediated and filled with petrolatum wax in 2008. However, the pipe within the casing contains a metal loss feature with a RPR<1 (from ILI data) and physical examination of the feature is not possible. This crossing is proposed to be replaced prior to reactivation.

To prioritize the casings that require mitigation work, the following criteria are used, in decreasing priority weighting:

1. The pipe within the casing contains external metal loss features with a Rupture Pressure Ratio (RPR) less than or equal to 1.10, as determined from in-line inspection data. A lower RPR is given a higher priority.
2. CP potentials of the pipe at the casing are below regulatory criteria (-850mV “OFF” or 100mV shift from polarized potential).
3. Presence of active external metal loss features on the pipe within the casing that have RPR’s greater than 1.10. A larger number of external metal loss features is given a higher priority.

4.7.2 Internal Corrosion

The deactivated sections have been purged with nitrogen and the integrity of the nitrogen blankets have been verified by pressure monitoring. Nitrogen provides an inert atmosphere that inhibits corrosion from occurring on the internal surface of the pipeline.

The 2007 BJ MFL ILI on the Hinton to Hargreaves segment indicated that there were no joints of pipe that had internal anomalies that were predicted to have a rupture pressure of less than 1.0. The ILI tool identified three pipe joints that had internal anomalies that were predicted to be deeper than 50 per cent of the pipe wall thickness. These features are not necessarily indicative of internal corrosion, since many MFL indications are a result of manufacturing or other anomalies. There has been no past evidence of internal corrosion on the reactivation segments.

No excavations have been completed to assess these anomalies as the segment was deactivated shortly after the inspection was completed.

No high resolution metal loss ILIs have been completed on the Darfield to Black Pines segment of the pipeline.

The plan for the detection and removal of internal corrosion defects will be the same as for external corrosion defects as described in 4.6.3.7.1.

Products to be transported through the reactivation segments will be similar to those which are currently transported in the TMPL system with the exception that very little heavy crude will be transported. Current KMC TMPL tariff agreements limit the BS&W (Basic Sediment and Water) to 0.5%.

The reactivation sections are planned to be maintained in a turbulent flow regime. Turbulent flow control solids deposition and keeps solids and water that may be present entrained in the product flow. The product stream in conjunction with the operating and flow characteristics, render the pipe wall in an oil-wet (i.e. non-corrosive) condition. KMC is committed to continued

monitoring through the use of in-line inspection and pigging programs along with a commitment to implement appropriate mitigation strategies where warranted.

4.8 Cracking

4.8.1 Seam and Body Cracking

A USCD tool was run in the Hinton to Hargreaves segment in 2007. The USCD report indicated that there were approximately 21 crack-like anomalies in the pipeline. Sixteen of these anomalies were predicted to be between 1 mm and 2 mm deep (approximately 12 to 25 per cent of the pipe wall thickness). The remaining five indications were predicted to be between 2 mm and 3 mm deep (approximately 25 to 40 per cent of the pipe wall thickness).

Four of the locations where 2 mm to 3 mm deep features were identified by the USCD tool were excavated and further assessed. No indications were found at two of these locations. The other two sites found linear indications that had depths of less than 10 per cent of the pipe wall thickness.

The USCD tool also identified one notch-like indication with a depth range of 2 mm to 3 mm. This feature was excavated and further assessed and was determined to be caused by grinder marks on both sides of the longitudinal weld.

One indeterminate feature was identified by the tool and was excavated and assessed. The feature was determined to be an irregular weld with a small, visible, pin hole.

Eighteen weld anomalies were also identified by the USCD tool. None of these features were field assessed.

No crack inspections have been completed on the Darfield to Black Pines segment.

Prior to reactivating the pipeline segments, Trans Mountain will run an axial flaw detection (AFD) ILI tool that is able to identify axially oriented features such as corrosion grooves, gouges and cracks.

Trans Mountain will also inspect the reactivated segments, within the first two years of operation, with a specialized high-resolution ultrasonic tool, to verify that no detrimental crack defects remain in the pipeline following hydrostatic testing. In addition, as is further discussed in Section 5.6, Trans Mountain will undertake a hydrostatic test of the reactivation segments in accordance with the requirements of CSA Z662, Oil and Gas Pipeline System requirements and KMC Standard MP4121, Main Line Hydrostatic Testing. Hydrostatic Testing has been established as an effective assessment and integrity verification technique for seam and pipe body cracking.

4.8.2 Stress Corrosion Cracking

Stress Corrosion Cracking (SCC) is a form of cracking that can occur beneath coatings that have disbonded from the pipe surface where there is an absence of adequate CP or when the disbonded coating shields the pipe from the cathodic current. It is possible for SCC to occur on coal tar enamel coated pipelines. Trans Mountain has confirmed a few existences of SCC on the NPS 24 pipeline.

Trans Mountain has confirmed indications of SCC on the Hinton to Hargreaves segment at KP 407 and KP 407.3. No SCC has been found in the Darfield to Black Pines segment. Repairs consisted of cutting the affected pipe out of the pipeline and replacing it.

The SCC at KP 407 consisted of three colonies with a maximum crack length of 3 mm and a maximum depth of less than 10 per cent of the pipe wall thickness. The cracks were oriented longitudinally. The pipe was located in a muskeg area with moist soil conditions.

The SCC at KP 407.3 consisted of one colony with a maximum crack length of 5 mm and a maximum depth of less than 10 per cent of the pipe wall thickness. The cracks were oriented longitudinally. The pipe was located in a rock/clay/sand mix soil with wet soil conditions.

Both SCC features appear in a section of pipeline where the 2012 test station readings showed low off-potentials (below -850 mV). As noted, Trans Mountain is reviewing the CP in these areas to determine if adjustments or modifications are required.

A USCD tool was run in the Hinton to Blue River section of the pipeline (which includes the Hinton to Hargreaves segment) in 2007. One crack field anomaly was identified. The feature was predicted to be approximately 1 mm to 2 mm (12 to 25 per cent) of the pipe wall thickness. The feature has not been assessed in the field.

Prior to reactivating the pipeline segments, Trans Mountain will run an AFD ILI tool that is able to identify axially oriented features such as cracks.

Trans Mountain will also inspect the reactivated segments, within the first two years of operation, with a specialized high-resolution ultrasonic tool, to identify the presence of sub-critical defects that remain following hydrostatic testing.

4.9 Dents

Dents may exist in pipelines as a result of the pipelines settling over rocks, from rock impingement due to soil movements (*e.g.*, freeze/thaw cycles), or from third-party damage. A high resolution GEOPIG ILI was completed in 2001 on the Hinton to Hargreaves segment and in 2003 on the Darfield to Black Pines segment.

The 2001 GEOPIG ILI identified 14 top side dents with a depth greater than 2 per cent of the pipe diameter. The largest top side dent identified was a 3 per cent dent. Bottom side dents were more frequent and are typical of construction through the rocky terrain of the mountains. One bottom side dent had a predicted depth of 6 per cent of the pipe diameter. Three bottom side dents had predicted depths of between 5 and 6 per cent. Four dents were identified with predicted depths between 4 and 5 per cent and 25 dents had predicted depths between 3 and 4 per cent.

Excavations were completed at 54 locations along the Hinton to Hargreaves segment. Dents were identified at 49 of the sites. At two of the sites, corrosion was found in the dents. In both cases, the dent/corrosion was not severe, the corrosion features were ground out, and the pipes were recoated. Gouges were found in dents at two locations. One was in a top side dent at approximately the one o'clock position and one was in a bottom side dent at approximately the six o'clock position. In both cases, the features were non-deleterious, the gouges were ground out and the pipes were recoated. Nine dents were found to contain scratches. Scratches are small surface level indications that do not have measurable depth. Eight of these defects were ground out and one was repaired with an epoxy filled sleeve. Four of these defects were located on the top side of the pipe and five were located on the bottom side of the pipe. The largest dent depth that was recorded as a result of the excavations was 2.15 per cent of the pipe diameter. This was likely due to rebounding of the dents once the indentors were removed rather than overestimation of the sizing of the features by the GEOPIG.

On the Darfield to Black Pines segment, nine dents with a predicted depth greater than 2 per cent of the pipe diameter were identified by the 2003 GEOPIG inspection. All of the dents were located on the bottom of the pipe. The largest dent identified was predicted to have a depth of 4.6 per cent. Two dents were predicted to have depths between 3 and 4 per cent. The remaining dents were all predicted to have depths between 2 and 3 per cent. No excavations were completed on the dents identified in the Darfield to Black Pines segment.

The low number and low severity of top side dents is an indicator that the public awareness program, the One-Call systems and aerial and ground monitoring programs are effective at limiting unauthorized activities around the pipeline. Also, there is relatively little construction activity that occurs in the vicinity of the Hinton to Hargreaves segment in Jasper National Park and Mount Robson Provincial Park.

Prior to reactivation, Trans Mountain will complete additional high resolution geometry ILIs as necessary to identify additional potential dent, wrinkle, or buckle defects that may exist and any associated repairs. The ILIs will also allow overlapping of the previous GEOPIG inspections to detect any potential ground movements proximate to the pipeline.

4.10 Third-party Activity

Trans Mountain has a public awareness program, signage along the rights-of-way, aerial patrols and ground patrols, and participates in the Alberta and BC One-Call systems. Trans Mountain has maintained these programs on the deactivated segments.

Trans Mountain's Public Awareness Program ensures that landowners adjacent to the rights-of-way, contractors using excavating equipment, emergency response agencies and the general public are made aware of the need to protect the operating pipeline from damage.

Signage is used to identify the pipeline rights-of-way at regular intervals and at all road and utility crossings. Besides serving to prevent damage to the pipelines from accidental interference, the signage includes an emergency contact number for the public to call if they spot unusual activity.

Right-of-way surveillance is conducted via aerial patrols. Aerial patrols help to prevent incidents by reporting unauthorized ground disturbance activities. The frequency of aerial patrol for the two segments to be reactivated is provided in Table 4.10.1.

TABLE 4.10.1

AERIAL PATROL FREQUENCY

TMPL Line/Segment	Summer (May to October)	Winter (November to April)
Edmonton to Barrier, BC	2/month (12)	1/month (6)

Field operations personnel also conduct day-to-day surveillance of the rights-of-way during the performance of their regular duties and report potential or existing encroachments.

4.11 Natural Hazards

The natural hazards program is designed to detect, monitor, and remediate sites which are deemed to present a risk of damage to or failure of the pipeline due to geotechnical or

hydrotechnical hazards. Trans Mountain has conducted natural hazards monitoring on the pipeline system since the early days of operation; however, a formal program to assess and monitor natural hazards was implemented in 1998.

In total there are 83 hydrotechnical sites that are being managed by the Natural Hazards Program on the Hinton to Hargreaves section of line and 9 hydrotechnical sites that are being managed on the Darfield to Black Pines segment. In addition, there are 9 geotechnical sites being managed on the Hinton to Hargreaves section of line and 2 geotechnical sites being managed on the Darfield to Black Pines segement of line.

In the original engineering assessment nine areas for potential mitigation prior to reactivation of the Hinton to Hargreaves segment were identified as part of the Natural Hazards Program. There were no areas of mitigation indentified in the Darfield to Black Pines segment. In 2013, the Natural Hazards Program identified an additional 15 sites for potential mitigation prior to reactivation for the Hinton to Hargreaves segment bringing the total number of sites for potential mitigation to 24 sites. No additional sites were identified on the Darfield to Black Pines segment. Table 4.11.1 includes a listing of all sites currently on the list for potential mitigation prior to reactivation.

If additional natural hazard sites are identified prior to reactivation, these will be added to the list for potential mitigation.

TABLE 4.11.1

NATURAL HAZARDS MITIGATION PRIORITY LIST (HINTON TO HARGREAVES)

Priority	KP	Site Name	Depth of Cover (m)	Comments	Condition	Action Plan
1	411.57	Rockingham Creek	0	Exposure noted in 2013 for a length of 1 m	Hi energy stream. Large boulders along bed and banks. Investigate potential for debris flow. Investigate option to isolate with diversion. Investigate options to mitigate with riprap or replace crossing.	Investigate debris flow. Develop mitigation plans.
1	420.3	Ghita Creek Debris Flood	0	Exposure noted in 2013 for a length of 0.2 m	Narrow stream, low flow, poorly defined banks, high energy with cascading drops. Flows through dense vegetation (but may have been cleared). Investigate potenital for debris flow. Investigate possible application of riprap or Armorflex. Located adjacent to CNR, poor access.	Investigate debris flow. Develop mitigation plans.

Priority	KP	Site Name	Depth of Cover (m)	Comments	Condition	Action Plan
1	452.72	Unnamed Creek Debris Flow (inactive line)	0	Exposure noted in 2012 for a length of 5 m	Wide channel, high energy. Pipe fully exposed close to being undermined. Scour d/s of pipeline. Investigate previous design. Consider line lowering. High channel slope not conducive to rock armour. Investigate line lowering or replacement	Investigate and develop mitigation plan.
2	348.04	Unnamed Creek	0.04	Low flow, wide channel. Investigate potential for debris flow.	Low energy, remote, no active erosion. Low flow, wide channel. Investigate potential for debris flow. Option to mitigate with riprap or Armorflex.	Investigate potential debris flow threat and remediate.
2	460.3	Aerial Span				Investigate if any threat to integrity. Conduct structural and pipeline assessments.
3	360.18	Snaring River	0	Exposure noted in 2012 for a length of 10 m	Exposure in main channel. Estimate moderate scour potential.	Investigate and develop remediation.
3	374.97	Cottonwood Creek	0	Exposure noted in 2008 for a length of 0.5 m	Low flow narrow, shallow channel. No natural instream hazards. Investigate potential risks due to proximity to hwy. Pipeline is currently protected by steel casing.	Assess. Riprap and Armorflex options designed prepared in 2013

Priority	KP	Site Name	Depth of Cover (m)	Comments	Condition	Action Plan
3	389.81	Minaga Creek	0	Mitigated in 2001 but exposure noted in 2008. A length of 2.5 m steel is exposed.	Wide stream large boulders along bed.	Investigate and develop options for remediation.
3	427.44	Fraser 5	0	Exposure and sinkhole were noted in 2013 on the right and left bank flood plains, respectively	1.27 m in channel cover on P/L BGC dwg shows sinkhole at left floodplain(cvr .37m) and wide degradation to 0 m cover at right floodplain. Right bank at inside meander. Right bank & beyond identified as 'sensitive soils". Develop plan to increase cover at right bank floodplain.	No in-channel threats. Investigate and remediate right bank floodplain.
3	461.18	Fraser 7	0	Exposure noted in 2013 for a length of 3 m	Wide channel, large boulders along stream bed and banks. Develop options for remediation. Diversion on floodplain may be possible	Investigate. Remediate with either riprap or pipe replacement
4	351.32	Vine Creek Debris Flood	0.19	Line was exposed in 2010 then temporary covered back by gravels and cobbles	Investigate potential for debris flow. Option to mitigate with riprap	Investigate potential debris flow threat and remediate as required.
4	386.72	Miette Encroachme nt 2	1	Active bank erosion - encroachment concern	P/L along outside meander bend. Bank erosion. There is no immediate threat and remediation is not recommended at this time. Monitor for changed conditions	Monitor. Develop contingency mitigation plans
4	438.6	Unnamed Creek	2.9	Eroded PL ROW	Small, shallow channel. Sufficient cover. No instream threat.	Investigate conditions, mitigate as required.

Priority	KP	Site Name	Depth of Cover (m)	Comments	Condition	Action Plan
5	338.1	Unnamed Creek 129	0	Exposure noted in 2013	Slow stream on row access to Athabasca River. Low energy, no access, no natural instream threats to exposed pipe, no traffic.	Investigate and mitigate as required
5	341.66	Unnamed Creek	0	Exposure noted in 2013 for a length of 0.5 m; encroachment is also a concern.	Narrow low flow low energy channel obscured by grass. Limited access, no instream threat.	Investigate and mitigate as required
5	347.8	Overlook North Slope	1.04		Shallow erosion gully. No immediate threat.	Long-term Monitor
5	385.97	Muhigan Creek	0	Exposure noted in 2010 for a length of 2.9 m (entire channel width)	Low flow, low energy channel 3 m wide. No instream hazards.	Investigate and mitigate as required.
5	403.99	Miette 5	0	Exposure noted in 2011 for a length of 3 m	Wide channel. Requires mitigation to right bank only. Investigate option to armour right bank and bed only	Investigate and mitigate as required.
5	416.34	Yellowhead Creek	0.3		Wide stream some boulders along bed. Slow water reach. Potential remediation will require isolation - investigate flows and methods to isolate.	Investigate and mitigate as required.
5	417.38	Fraser 1	0.68		Possibly vulnerable to scour.	Investigate and mitigate as required.
5	423.83	Fraser 2	0.45		Low cover.	Investigate and mitigate as required.

Priority	KP	Site Name	Depth of Cover (m)	Comments	Condition	Action Plan
5	427.84	Fraser 6	0.34		Low cover.	Investigate and mitigate as required.
5	439.29	Unnamed Creek (inactive line)	0.29	Scouring by upstream hanging culvert	No instream hazard. Assess risk of vehcle impact (proximity).	Investigate and perhaps remediate with riprap apron
5	459.45	Tunnel Site (inactive line)	0	Exposure noted in 2011 for a short length of pipe	Investigate lack of cover	Investigate and remediate as required.

Mitigation measures will be developed in the detailed engineering and design phase. Options will include armouring of the crossings with additional fill or other protective measures (rock blanket, concrete matting) or replacement of the pipe in the crossings with added depth of cover. Where a pipe replacement option is necessary, trenchless, isolated open cut, and open cut methods will be considered after an assessment of the hydrological and aquatic conditions and other technical and environmental factors. The results of the assessments will be filed with the NEB prior to reactivation, if required.

In addition to the mitigation measures at the known priority sites, Trans Mountain will run a high resolution geometry ILI tool prior to reactivation. The geometry tool data will be integrated with the data from the GEOPIG inspections completed in 2001 and 2003 to identify pipe movements that may have been caused by slope instability, river scour, or other geological, geotechnical, or hydrologic phenomena.

4.12 Other Threats

As part of the threat assessment review, other potential threats were reviewed for the reactivation sections including:

- Forest fires (primarily forest fires around Japser National Park);
- concomitant failures (where a failure of one pipeline can result in impacts on adjacent pipelines);
- wind / snow loading; and
- potential integrity issues with older pipe fittings.

4.12.1 Forest Fires

Experience indictates that where a pipe is buried in a cleared right-of-way forest fires do not constitute a significant loss-of-containment hazard since the right-of-way acts as a fire break, and the ground cover acts to insulate the pipe. Industry experience would suggest that forest fires are not a threat for buried pipelines.

4.12.2 Concomitant Failures

Concomitant failures occur where the catastrophic failure of one pipe (typically a natural gas pipe, in which rapid decompression of a compressible fluid results in the formation of a blast crater, and in which the ensuing release of natural gas is readily ignitable), can result in the uncovering of an adjacent pipe, which may become involved in an ensuing fire. Although the reactivation section, part of the TMPL (Line 1), will lie parallel to Line 2 for most of the route, this scenario was not considered viable, since both lines are LVP pipelines.

4.12.3 Wind / Snow Loading

Wind/snow loading was identified as a potential threat at the 37 m aerial crossing identified on the Hinton to Hargreaves section. This is not currently considered to be a significant threat. Wind and snow loading on aerial crossings in general are managed through the KMC Natural Hazard Management Program (NHMP).

4.12.4 Older Pipeline Fittings

In 1985 Trans Mountain became aware of an issue associated with the use of pressure containing sleeves and fittings that were welded to the mainline pipe using cellulosic welding rods on operating pipelines containing flowing liquid. Hydrogen-induced cracking may occur due to higher levels of hydrogen produced by cellulosic welding consumables and from rapid cooling due to the flowing liquid in the pipeline. Regulatory agencies encouraged operators to assess the potential for hydrogen cracking to occur on their pipeline systems and if the operator determines that there is a risk to complete inspection and repair programs.

Potentially affected repair sleeves and fittings include those installed prior to 1985 when welding procedures were changed to remove the use of cellulosic welding rods.

In response to this threat Trans Mountain completed an inspection and repair program on the Trans Mountain system. By June 1991, all of the Pressure Containment Sleeves between Hinton and Hargreaves had been inspected and repaired. No sleeves were present between Darfield and Black Pines; however, a welding ring at KP 800.91 was inspected in November 1988.

Between 1995 and 2003 Trans Mountain installed a number of composite and clockspring sleeves on the pipeline system. Since these sleeves were installed, Kinder Morgan Canada (KMC) has abandoned the use of Epoxy Sleeves and Clock Springs in favor of Petrosleeves for the majority of pipeline repairs. Kinder Morgan Canada has since implemented a program to inspect or remove any Epoxy Sleeves and Clock Springs on the pipeline. Results of the 2007 BJ MFL tool run from Edson – Hargreaves indicate that most of the Epoxy Sleeves and Clock Springs from Hinton – Hargreaves were still in place at the time of inspection.

Prior to reactivation, Trans Mountain will complete inspections and replacements or repairs of existing composite sleeves on the reactivation sections of pipline.

4.13 Consequence Reduction

Trans Mountain is currently assessing consequence reduction options on the Hinton to Hargreaves and Darfield to Black Pines segments. These studies will be completed in conjunction with risk studies, environmental sensitivity studies, and the engagement of Parks Canada and BC Parks. The studies are expected to be complete in Q2, 2015.

Consequence reduction will generally consist of automating select existing RMLBVs and/or installing new automated RMLBVs or check valves at locations that are most advantageous in reducing the impact of a pipeline rupture. The valve automation/placement studies assume a worst case rupture (*i.e.*, a complete break). The calculated escaped volume is based on the maximum flow rate of the pipeline, the time required for the leak detection system to generate an alarm, and the time required for the pipeline operator to shut down the pipeline and close the RMLBVs.

An ancillary benefit to additional RMLBVs will be pressure monitoring at more locations. Additional pressure monitoring is expected to improve leak detection capabilities.

5.0 REACTIVATION STEPS

The various steps to prepare for and achieve reactivation are discussed in the following sections. A preliminary schedule for these activities is included in the Trans Mountain Expansion Project Application, Volume 4B, Section 3.2 along with the preliminary pipeline construction schedule.

5.1 Initial In-Line Inspections and Repairs

As discussed in the previous sections, Trans Mountain will run three ILI tools, along with an initial gauging tool in the segments to be reactivated, prior to hydrostatic testing. The tools will identify metal loss, mechanical damage, and axially oriented cracks.

Once the ILI results are received, Trans Mountain will do a number of digs to verify the tools' sizing accuracy and to assess potentially injurious anomalies. Since the pipeline is inactive and has been purged with nitrogen, any required repairs will be completed as cut-outs (*i.e.*, replacements of the damaged sections of pipe with new pipe).

5.2 Natural Hazards Mitigation

After the initial ILI program, Trans Mountain will mitigate the stream crossing hazards already identified and any other hazards identified during ongoing assessments.

5.3 Remote Main Line Block Valve Automation and Installation

In conjunction with the natural hazards mitigation program, Trans Mountain will complete the automation of existing RMLBVs and the installation of new RMLBVs that are identified during the ongoing study work.

Existing access roads and power lines will be utilized to the extent possible and any new infrastructure required to automate existing RMLBVs or install additional RMLBVs will include consultation with local Aboriginal groups and stakeholders.

Remote main line block valves will also include pressure monitoring devices that will communicate with the SCADA/Leak Detection system.

5.4 Additional Maintenance Activities

In conjunction with the RMLBV automations and installations, the existing RMLBVs will be inspected and refurbished, if necessary. Existing pipeline fittings will also be inspected and replaced if necessary and unnecessary small bore valves and piping will be removed.

5.5 Additional Construction Activities

As part of previous deactivation work, and in order to isolate the deactivated pipeline segments from the active pipeline segments, some fittings and piping that connected the pipelines to pump stations were removed. Modifications to piping were also made at other locations to allow the active NPS 24 pipeline segments and the larger diameter loops to form a continuous pipeline system. To allow for ILI work to proceed, the following activities will be required:

- From Hinton to Hargreaves:
    - installation of a temporary sending trap at the former Hinton trap site;
    - installation of approximately 250 m of NPS 24 pipe between the station isolation valves at Jasper Pump Station;
    - installation of approximately 200 m of NPS 24 pipe at the former Yellowhead Pump Station site; and
    - installation of a temporary receiving trap at the Hargreaves trap site.
- From Darfield to Black Pines:
    - assessment and possible upgrade of the existing sending trap at Darfield Pump Station; and
    - installation of a temporary receiving trap at the Black Pines RMLBV site.

These temporary installations and modifications will be coordinated with the permanent modification work required at some of these sites.

5.6 Hydrostatic Test

The final step in the reactivation process will be hydrostatic testing of the pipeline segments to qualify them at a minimum to their former MOPs. Where possible, portions of the segments will be tested to 100 per cent of the pipe SMYS. Hydrostatic testing will be conducted in accordance with CSA Z662, Oil and Gas Pipeline System requirements and KMC Standard MP4121, Main Line Hydrostatic Testing. Hydrostatic testing will ensure that a 1.25 safety factor is established prior to the segments returning to operation. The operating conditions of the reactivated pipeline are expected to be similar to what they were prior to deactivation.

5.7 Final In-Line Inspection

As discussed in previous sections, Trans Mountain will conduct an ILI of the reactivated segments within the first two years of operation with a specialized high-resolution ultrasonic tool to identify the presence of sub-critical defects that were not removed by means of hydrostatic testing. Any defects identified will be assessed and a repair program will be initiated, as necessary.

6.0 REFERENCES

6.1 Literature Cited

Canadian Standards Association. 2011. Z662-11, Oil & Gas Pipeline Systems. Canadian Group.

National Energy Board. 1999. Onshore Pipeline Regulations. SOR/99-294. Government of Canada, National Energy Board, Calgary, Alberta. Current to October 1, 2013.

7.0 APPENDICES

Appendix A Threat Assessment