Line 5 inspections

Regular examinations of the pipe, both inside and out

Prevention is a key component of safety at Enbridge. Our proactive inspection program allows us to monitor the fitness of our pipelines from both the inside and the outside.

We take extra precautions on the Line 5 Straits of Mackinac crossing, with regular inspections that make this crossing the most inspected segment of pipe in our entire North American network. These measures include:

- Thoroughly evaluating the pipe's interior every five years, using our in-line inspection tools. These tools provide a level of detail similar to MRIs in the medical industry, allow us to examine the interior walls of our pipes inch by inch, and alert us to features that may require a closer look.
- Regular visual inspections of the exterior of the pipe, using expert divers and/or remote operated vehicle (ROV), every two years (twice as often as federal regulations require). These external inspections provide a thorough, detailed look at the exterior of the pipe and its immediate environment.
- In 2014, we retained GEI Consultants Inc., an independent firm founded by Harvard and MIT geotechnical engineers, to assess the mussels found along our Line 5 Straits crossing. GEI examined several factors, including mussel weight and mussel secretions, and determined that mussels accumulated on Line 5 in the Straits of Mackinac have no impact on the pipeline **(the study is available online at www.enbridge.com/Line-5)**.

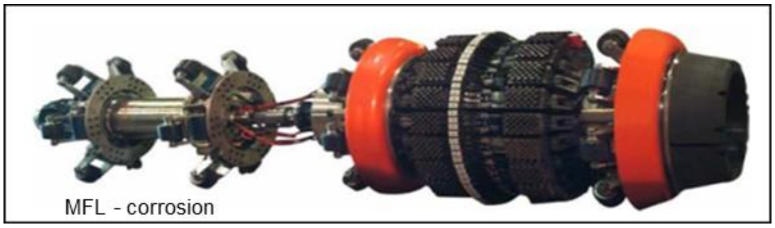
Line 5 Inspection Results

As mentioned, internal inspections are done every five years using sophisticated tools that run through the pipe and examine it from the inside, inch by inch. These tools alert us to any issues in the pipeline that may require immediate attention, further analysis or maintenance. Data collected from those scans is analyzed by specialized computer programs and expert engineers, and is continually compared to get a full picture of what's happening in the pipes.

In the past five years, the four-plus miles of pipe under the Straits have been internally inspected by three different tools, checking for everything from deformations to girth-weld features to metal loss in the pipe wall. A total of 13 in-line inspections have been done since 1987.

The next in-line inspections—for metal loss, deformation and circumferential cracking—are planned for 2018.

Metal Loss/Corrosion



Whether it's the Eiffel Tower or underwater pipelines, steel infrastructure needs to be maintained and protected from corrosion. For the Eiffel Tower, that involves a new coating of paint every seven years to protect the iconic structure from the elements and keep it safe for millions of tourists. At Enbridge, we take a comprehensive approach to protecting and maintaining our pipelines to ensure the safety of the public and protection of the precious Straits of Mackinac waterway.

Our engineering analysis of the pipelines under the Straits of Mackinac tells us these pipes are in good condition, in almost 'as new' condition in fact. But how do we know that? One of the many ways we assess the fitness of our pipelines is through the analysis of data collected by specialized tools. These tools can determine if any of the tiniest of blemishes found on the steel is an indication of a developing problem. We'll get into the data in a moment, but first, let's talk about how we prevent corrosion.

We keep corrosion at bay—inside and out—through various means and measures. Externally, the parallel pipes travelling under the Straits of Mackinac are covered by a tough enamel coating that's impermeable to water, providing a barrier protecting the steel from exposure to the elements. The potential for corrosion is further reduced by the use of a secondary protective measure called cathodic protection, where we apply a low-level electrical current to the pipeline to protect the steel from reacting to the environmental conditions.

We also minimize the potential for internal corrosion in a variety of ways, including:

- The strict enforcement of quality standards for every batch of product entering our system, including viscosity, density, temperature, and sediment-and-water content;
- Injecting corrosion-inhibiting chemical additives to the oil in our pipes; and
- Regularly cleaning the interior walls of our pipes with special tools.

Although the potential for corrosion is low because of all the measures we take to protect the pipelines, we routinely perform in-line inspections (ILI) with high-tech tools similar to technology used in the medical industry. They scan the pipelines inch by inch, and collect data that our expert engineers pore over and analyze to get a full picture of what's happening.

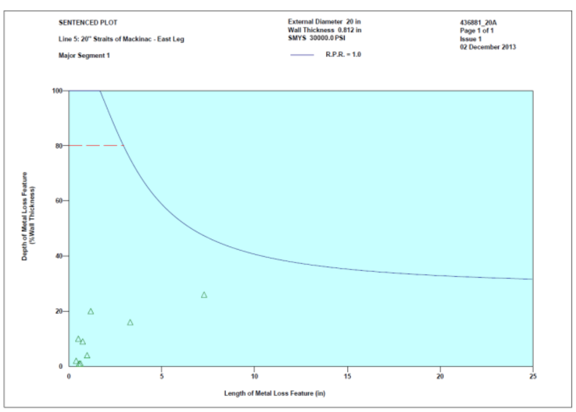
Metal loss in the nearly one-inch-thick walls of Line 5's steel pipe travelling under the Straits, is one of the conditions measured by the tools, even at minute levels. Our in-line inspection tools are capable of identifying small anomalies, called features, on both the inside and the outside surfaces of our pipes. Repeat inspections provide updated information and verify our engineering analysis.

The primary tool we use for metal loss and corrosion is the Magnetic Flux Leakage (MFL) tool. MFL technology uses powerful magnets to magnetize the steel in the pipeline. As the tool passes through the pipeline, precise measures of any changes to the magnetic field are measured. If any corrosion or thinning of the metal has occurred, the measure of the strength of the magnetic field is distorted, revealing an anomaly along with its size—both depth and length—and its location on the pipes.

The results of the MFL runs are reviewed by Enbridge pipeline engineers. Any anomalies are assessed for whether they are acceptable corrosion pits, or if they are large enough to require repair. If what's found reaches a certain threshold, repairs are done. For the Straits, this would generally be through the installation of a steel reinforcing sleeve that would strengthen the pipe at the corrosion location.

So what did our MFL tool find?

The left and right plots below were taken directly from the summary sections of the 2013 MFL inspection reports for the East and West Straits pipelines, respectively (Line 5 branches into two parallel, 20-inch-diameter lines as it travels under the Straits of Mackinac). All of the metal loss features that were measured by this high-resolution tool are reported by the green triangles. The vertical axis represents the depth of the features, and the horizontal axis represents their length. The blue line represents the allowable corrosion depth and length for the pipeline to safely transport its product.



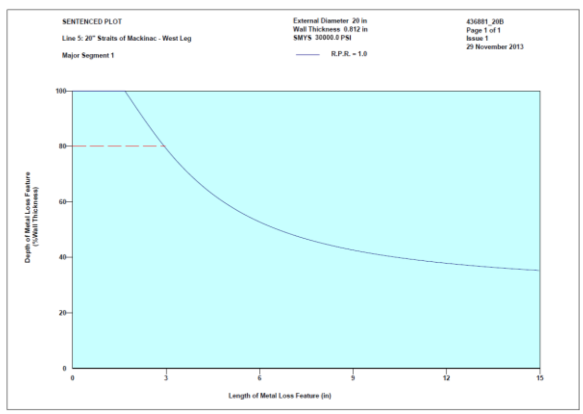


Figure 2 –2013 MFL Inspection Corrosion Results

As shown in the above figure, there were **nine metal loss corrosion features** identified by the MFL tool on the nearly five-mile East Straits pipeline, all of which were **located on the on-shore portion** of the pipeline. For these nine features, the average maximum depth was **10 percent of the wall thickness,** and the average length was 1.7 inches. The deepest was **26 percent** and 7.3 inches long, which makes it the longest feature as well—but still only half as deep as it would need to be to require repairs, as set out by regulatory standards. The allowable limit for safety, as set out by those regulatory standards, is a function of the metal loss size, pipeline properties, and operating parameters, and is represented by the blue curved line in these figures. The features that were found fall well below the line, which means well within safety thresholds.

Pipeline regulations require immediate action for areas where metal loss is greater than 80 percent of the wall thickness, or a predicted burst pressure is than less than the maximum operating pressure (MOP). Enbridge undertakes repairs when features are deeper than 50 percent of the pipe wall thickness, or based on operational safety factor calculations, which is designed to ensure the defect is repaired when its predicted failure pressure is well above the MOP.

All of these features found by the MFL tool were on the inside of the pipe, which means there was no external metal loss features on the East pipeline (remember, the outside of the pipe is covered with a tough enamel coating that provides a barrier between the steel and the elements, namely water).

For the West Straits pipeline, there were **no metal loss features** identified by the MFL tool on either the inside or outside of the line, which is why there are no green triangles on the right-hand-side Figure 2 plot.

Additionally, Enbridge conducts its own assessments of these features, above and beyond those conducted by the ILI vendor, to assess and evaluate the accuracy of the ILI tool; all nine were assessed by our engineers, and considered well within safety thresholds. If they were found to be above the acceptability limits, or the blue line in Figure 2, preventative maintenance action would be taken.

In addition to the metal loss anomalies shown in Figure 2, the ILI report also shows other features with reported length and depth that are characterized as mill anomalies. All pipe, even brand new, will contain some anomalies or imperfections, most of which will never grow or represent a threat. In the case of Line 5, which consists of specially manufactured seamless piping for extra strength and safety, some variations in wall thickness result from (and are expected from) the manufacturing process itself.

These wall thickness variations passed the original hydrotests and been safely accommodated by the pipelines since construction. They are picked up and reported by the corrosion tools, and while stable in nature, are nonetheless monitored and assessed from inspection to inspection, as shown in Figure 3 and described in Table 1.

Taken directly from the 2013 ILI Metal loss inspection reports, Figure 3 gives a graphical representation of the depth of features found along the East and West pipelines, including both metal loss and mill anomalies. The chart is categorized by total features, and then subsequently by increasing depth from front to back. The peak depth of mill anomalies on the East and West pipelines was **37 and 41 percent** of the wall thickness, respectively. Table 1 below shows the distribution of features for both Straits pipelines, where there were **141 and 294 features** identified by the MFL inspections of the East and West pipelines, respectively. As stated above, these features all exhibited a depth below 50 percent of wall thickness and well within safety thresholds.

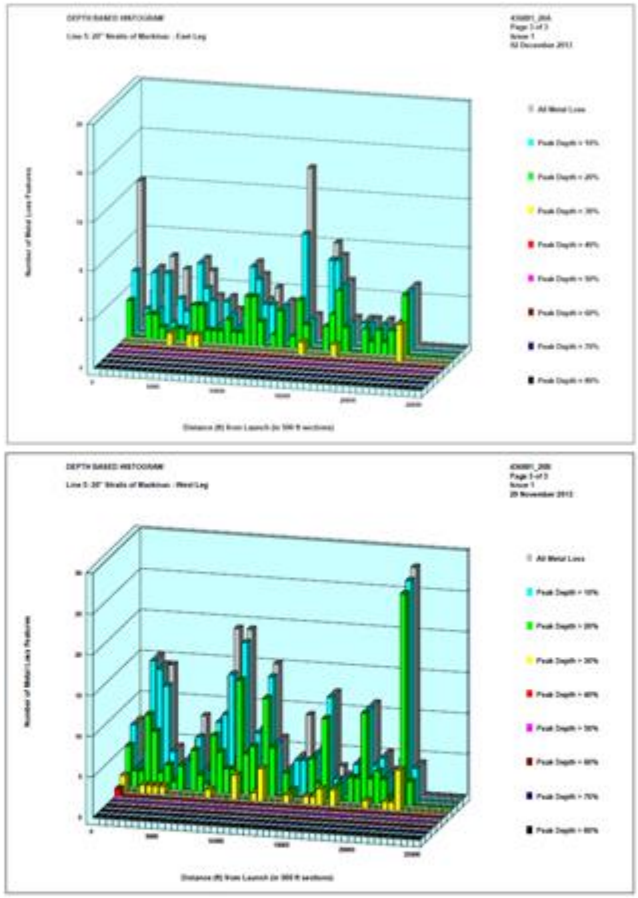


Figure 3 – Summary of Number of Features by Depth of 2013 (East Leg) Metal Loss Inspections

Table 1 – Summary of metal loss and mill anomalies identified by 2013 MFL inspections

Features by Depth (percentage of wall thickness)	Number of Features	
	East	West
Predicted peak depth of > 50%	0	0
Predicted peak depth of > 40% and ≤ 50%	0	1
Predicted peak depth of > 20% and ≤ 40%	71	188
Predicted peak depth of ≤ 20%	70	105
Total	141	294

The low quantity of corrosion features identified by the MFL inspections are as expected, given the Line 5 crossing's high-performance enamel coating, the current flow of the lake crossing environment, and low corrosivity of the NGL and light crude transported product.

The 2013 corrosion inspections represent the latest in a long-standing program of regular inspections that have been established as part of our integrity management program. Subsequent in-line inspections will continue as part of this program on a five-year interval to

continually monitor these features for any changes or growth. Mitigation activities will be conducted as required by these assessments to ensure the ongoing safe operation of the line.

Deformations

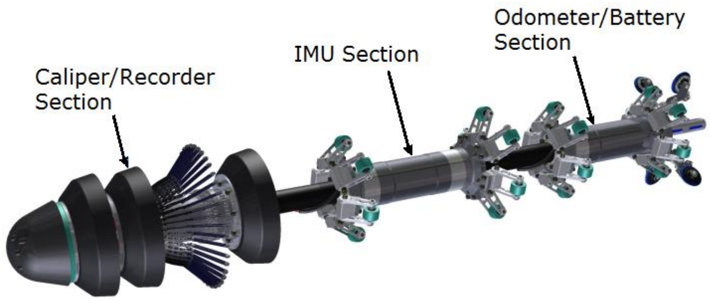


Figure 4: Baker Hughes Geopig Geometry ILI Tool

Imagine driving along a highway, and seeing a small rock spit out from the rear tire of the truck ahead of you and ping off your windshield. While the resulting pit or chip is not going to affect the performance of your car, it’s still important enough in the interests of safety and structural integrity to have that windshield repaired.

Rocks, as it turns out, are also the most common cause of deformations—also known as dents—on steel pipelines.

We take various proactive precautions to prevent deformations from happening, including the promotion of a public awareness program—and, in the case of the Line 5 Straits of Mackinac crossing, the placement of visible signage to warn nearby water traffic, awareness briefings to those who captain the larger shipping vessels, and the imposition of a "no-anchor zone" clearly marked on National Oceanic and Atmospheric Administration (NOAA) nautical maps.

It’s important to note that Line 5’s twin pipelines (Line 5 branches into two parallel 20-inch-diameter lines under the Straits of Mackinac) enter the open water of the Straits at a depth of 40 to 50 feet, protecting Line 5 from incidents involving anchors or moving ice packs. The pipes are laid in a dredged ditch until the Straits reaches a depth of 65 feet; at depths of more than 65 feet, the pipes are secured to the lakebed using 10-foot-long screw anchors and held in place using metal saddles.

Our engineering analysis of the pipelines under the Straits of Mackinac tells us these pipes are in good condition, almost the same as when they were originally constructed.

How do we know that?

For one, our specialized tools can determine if there are any changes in the pipe wall that need repairs to prevent them developing into a problem.

We check for deformations using Caliper In-Line Inspection (ILI) tools, which use spring-loaded arms to record the shape of the inside surface of the steel pipe. The tool physically measures variances in the internal diameter of the pipeline to identify mechanical damage that may have occurred. These tools tell us where these features are located on the pipes—on top, underneath, on the side—and provide their GPS locations. Caliper ILI tools are so precise they can also measure specific characteristics of deformations, such as their size and whether they're smooth or sharp. The tool that is utilized by Enbridge for these inspections is capable of measuring very small anomalies of approximately 0.1" (or 0.5% of the diameter).

In order to differentiate true dent measurements from tool noise (where the caliper arms are bumping over girth welds, fittings, valves, etc.), the vendors will typically set a reporting cutoff of nothing smaller than 2% of the pipe diameter. Enbridge never-the-less requires a 1% reporting cutoff be employed when complex features (wrinkles, dents in close proximity to corrosion or other dents, or multi-apex dents) are encountered, accepting the possibility that defects may be reported where the indication is merely due to tool noise.

Our expert engineers and external specialists pore over the data that's collected, completing a preliminary review within hours to quickly identify anything that requires immediate action, followed up by a deeper analysis over the following weeks and months, to identify and locate features within the pipeline that require closer attention over the longer term.

The data collected is also layered and compared with findings from other in-line tool inspections that look for corrosion or cracking to provide a full picture of what's happening in the pipelines.

So what did the Caliper tool find?

Below, in Figure 1, are tables that are directly excerpted from the summary section of the 2013 East and West Straits Caliper in-line inspection reports that summarize the deformations that were measured during the most recent Straits inspection.

The tool found **two dents** on the East Straits pipeline. The largest dent had a width of eight inches and a length of eighteen inches. There were no dents identified on the West Straits crossing.

Summary of Pipewall Deformations

Deformations		Dents				Ovalities	Inward Wrinkles	Outward Wrinkles
		All (≥ 1%)	≥ 6%	Top of Pipe	Near GWD			
Total Number		2	0	2	0	0	0	0
Largest	Size (%OD)	1.50		1.50				
	Absolute Distance (ft)	19,797.9		19,797.9				

Summary of Pipewall Deformations

Deformations		Dents				Ovalities	Inward Wrinkles	Outward Wrinkles
		All (≥ 1%)	≥ 6%	Top of Pipe	Near GWD			
Total Number		0	0	0	0	2	0	0
Largest	Size (%OD)					8.75		
	Chainage (ft)					15,478.71		

Figure 1 – Summary of 2013 Caliper ILI Inspections for the East (top) and West (bottom) Pipelines

Figure 2 was directly excerpted from the East Straits Caliper ILI report and shows the depth and location distribution of all dents identified during the 2013 inspection. There is no similar figure for the West pipeline because no dents were identified in the 2013 West Straits Caliper in-line inspection.

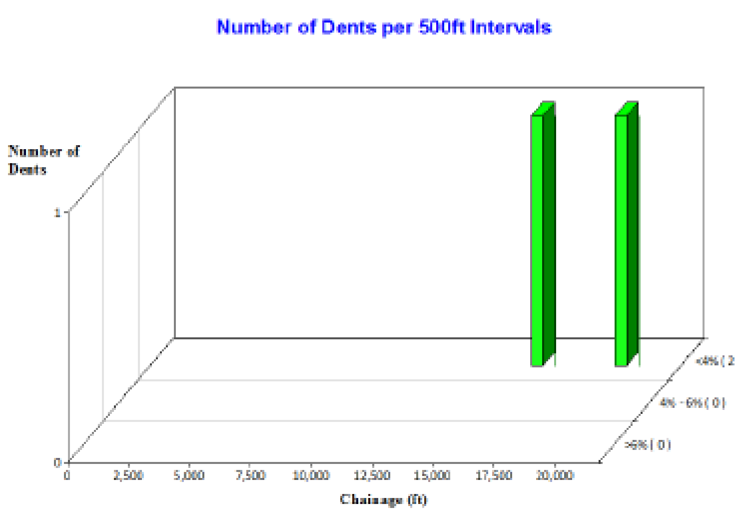


Figure 2 – Distribution of dents on East Straits pipeline as identified by 2013 Caliper ILI

Engineering analysis tells us these dents pose no threats to the safety of the pipeline and they fall below the regulatory repair threshold, which is two percent depth for topside dents and six percent for bottom-side dents. Nevertheless, these deformations were further inspected by divers in 2014 to confirm our engineering analysis. In these locations there were no actual pipe wall anomalies identified on visual inspection, with the indications resulting from tool noise. We continue to monitor the condition of the pipe, and will take additional measurements with future in-line inspections to maintain the fitness of the pipelines.

On the West Straits, **two ovalities** (where a pipe deviates from its normal circular shape) were recorded; both of these ovalities had widths of 10 inches, lengths of 40 inches, and a maximum depth of 8.75 percent of the pipe's diameter. There are no regulations for ovality limits, but Enbridge sets its own specifications of a 10 percent depth limit, and the ovalities measured well below this. There were zero ovalities identified on the East Straits crossing.

These pipelines have been in service for over 60 years with virtually no denting damage occurring. This performance is not by accident; rather, it is a direct result of the original design which used very heavy wall pipe to protect against outside force, as well as the care taken during the original construction and Enbridge's ongoing preventative awareness program. These pipelines will continue to be inspected on a regular schedule using inline technology every 5 years and visually every 2 years, and maintenance activities occurring as required, ensuring the continued safe operation into the future.

Cracking

General Electric USDuo Crack Inspection Tool

Imagine taking a piece of steel, and bending it back and forth repeatedly. Certainly, it would take a significant amount of force, but even steel, with its strength and malleability, can grow fatigued enough to the point where a crack will form.

When this happens, it constitutes what's scientifically known as stress-induced separation of metal, which is what the Pipeline and Hazardous Materials Safety Association (PHMSA) defines as cracking.

For the Line 5 Straits pipelines (Line 5 branches into two parallel 20-inch-diameter pipes as it travels under the Straits of Mackinac), the primary form of cracking that requires active management is 'circumferential cracking' at the locations where pipes are welded together – the girth welds.

At the Line 5 Straits crossing, to minimize any pipeline bending stress, Enbridge uses a sturdy screw-anchor system, affixing Line 5 to the Straits lakebed. The Line 5 Straits crossing is also the thickest segment of pipe along our North American network, at a minimum of 0.812 inches. Finally, we have rigorous inspection and monitoring programs in place to assess any conditions that might indicate a crack in the steel could potentially grow to result in a leak.

Our engineering analysis of the pipelines under the Straits of Mackinac tells us these pipes are in excellent condition, almost as new as when they were built and installed.

How do we know that?

Our specialized in-line inspection tools can determine if there are any crack anomalies that need repairs to prevent them developing into a problem. We'll talk about the test results in a moment. First, it's important to understand what risks we assess and manage.

We're focused on preventing potential cracking fatigue at the girth welds. Our in-line inspection program helps monitor the pipeline integrity condition, but we also take proactive care to minimize the potential for the development of cracks through other measures, such as span management. Long spans can potentially cause high bending stresses, and cause pre-existing girth-weld imperfections to grow through cracking. Enbridge performs bi-annual span inspections of the Straits pipelines, and installs supports at spans that exceed our 75-foot length criteria. This maximum span criteria is very conservative, representing half of the safe span length as determined through a 3rd party stress analysis. Furthermore, the actual spans distances tend to be much shorter, with the current average span distance being less than 50 feet. This program of span management is designed to ensure the bending stresses at girth-welds are maintained to a very low level.

To assess flaws that weaken the strength of the pipe when it's under loading, Enbridge follows British Standard (BS) 7910 in its fracture and fatigue assessment—the same standard used to assess the structural integrity of airplanes, whose steel wings bend and give under the pressure and stress of wind. Unlike an airplane's wings, our pipelines are prevented from bending or moving underwater.

In 2014, Enbridge conducted two separate girth-weld cracking inspections—one using a "free swimming" circumferential crack inspection tool, and the other using a tethered circumferential crack inspection tool. The tethered tool stops at each girth weld location to examine the weld condition with high resolution ultrasonics—similar to that of a medical exam. The data from the tool is then transmitted to a technician on the water surface for a real time assessment of the weld.

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What did our girth-weld inspections tell us?

Figure 1 (below) shows that all identified girth weld features were shallow, relative to the Line 5 Straits crossing's nearly one-inch-thick pipe wall. All girth welds will contain some anomalies or imperfections, and most will never grow or represent a threat. The table references four categories of features by depth. While a number of circumferential crack-like anomalies in the steel were identified, these anomalies are well within the safety margin and assessed to be minor, with the deepest being in the range of 39-78/1000ths of an inch. Such assessments involve complex scientific calculations, and as we've already mentioned, applying the same engineering methods used in the evaluation of the structural integrity of airplanes.

Depth (mil)	Crack-like Quantity
< 39	12
39 – 78	2
79 – 118	0
≥ 119	0
Total	14

Table 5 – Distribution of the crack-like anomalies according to depth

Depth (mil)	Crack-like Quantity
< 39	20
39 – 78	1
79 – 118	0
≥ 119	0
Total	21

Table 5 – Distribution of the crack-like anomalies according to depth

Figure 1 – Results of East (left) and West (right) 2014 GW NDT UCC in-line inspections

All identified girth weld anomalies were assessed by Enbridge using industry accepted methods that consider the anomalies' size, material, and expected stresses. The engineering analysis was performed immediately following in-line testing to assess the current fitness-for-service of each feature identified by the inspection. The minimum factor of safety of these anomalies was assessed to be 2.4 times the Maximum Operating Pressure. This confirms to us that the cracking threat on the pipeline has been demonstrated to be minor.

As an additional validation, field investigations were performed for the East and West segments on the onshore portion of the Straits pipelines. Figure 2 below, from the field inspection's non-destructive evaluation report, shows the inspection results for ILI feature 341436. This feature was identified by the ILI tool as an external crack-like feature less than five percent deep. Field investigation found no cracking, discovering instead a small surface anomaly that was removed by grinding. This reflects the sensitivity of the ultrasonic inspection tool to recognize the smallest of features and identify them for further assessment.

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Figure 2 – Field Results of East Segment in-line Inspection

Other engineering analyses are also performed to assure the continued fitness-for-service of the line. This includes pressure cycle monitoring on a frequent basis to ensure operating pressures remain at appropriate levels to minimize any pressure-related fatigue.

In conclusion, Enbridge’s comprehensive program is designed to address the prevention of defects followed by regular ongoing monitoring to assure the effective performance of the prevention elements. Mitigation is then conducted as required in order to maintain an appropriate margin of safety for continued operation. For the recent crack inspection program, all circumferential cracking features were inspected and shown to be minor in nature. Most, if not all, are benign weld anomalies that are not growing; nevertheless, all anomalies will be monitored repeatedly for growth through future inspections.

Got a question about Enbridge's Line 5 that you don't see answered here?

Communication is a two-way street. We want to hear from you, and address any concerns you may have about our pipeline operations. You can contact us in the following ways:

Call us toll free at 1-855-869-8209;

E-mail us at line5info@enbridge.com; or

Write to us at:

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We will respond promptly to calls and e-mails.