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Questions Answered By NDT Inspection for Forcemains in Service

Dwayne Hofstetter, Conestoga-Rovers & Associates, Waterloo, Ontario
Brad Marin, Conestoga-Rovers & Associates, Waterloo, Ontario

1. ABSTRACT

With the acceptance of high-density polyethylene (HDPE) as an approved material and improvements in horizontal directional drilling (HDD) technology, many municipalities are adding significant amounts of HDPE pipe material to their infrastructure inventory. Conestoga-Rovers and Associates (CRA) was retained by Vale Canada Ltd. (Vale) to perform non-destructive testing (NDT) and a pipe condition assessment of 610 millimeter (mm) (24 inch) and 750 mm (30 inch) HDPE mains at the Vale Frood-Stobie Mine site in Sudbury, Ontario. The NDT method was selected to allow the existing xxx mm (24 inch) concentrate and 500 mm (30 inch) tailing mains to remain in service without hindering plant operations, therefore reducing a costly shutdown in production and eliminating surge pressures at start-up. Automated ultrasonic testing (AUT) of the pipe walls provided a detailed view of the circumferential pipe wall thickness.

The pipe condition assessment was to include an external visual inspection of the pipe circumference documenting surface damage. The purpose of the inspection was to ensure the mains were capable of withstanding a planned earth excavation and grading project that would include the complete removal of earthen cover and bedding material. As a result of this project, the pipe would be totally exposed for a length of approximately 1.6 kilometers (km) (1 mile). The pipe condition assessment was considered to be reasonable due diligence because of the break history on these mains.

The following paper will provide a case study of the Frood-Stobie concentrate and tailings mains in Sudbury, Ontario (see Figure 1. Key Map).

2. INTRODUCTION

As part of its mining operation, Vale had previously replaced some of the existing concrete pressure pipe (CPP), which was originally installed in 1966, with HDPE pipe, in 1989. The CPP main was likely replaced due to the aggressive wear on the pipe. In preparation for the planned earth excavation and grading project, Operations noted a number of breaks within the existing HDPE forcemain and wanted to be provided with a pipe condition assessment on the forcemains. Following a background review of the INCO Issued for Quotation drawings, Operations replaced the original CPPs with 350 mm (14 inch) diameter HDPE SDR-11 pipe and 500 mm (30 inch) diameter HDPE SDR-11 pipe, respectively.

To determine the condition of the forcemains, CRA reviewed all available NDT technologies. However, site constraints, including the following, played a key role in determining which NDT method would be most suitable:

- Limited accessibility (no valve chambers within the study area)
- Existing pipe material

- Availability of technical crews
- Speed of testing
- Active process pipe (tailings/mining slurry being transferred)
- Reliance on the testing method to establish the wall thickness
- Cost of testing procedure
- Differential densities of the fluid within the pipe itself

Due to the constraints listed above, CRA considered all available NDT methods to carry out the pipe condition assessment of critical forcemains. Based on the installation date, the HDPE pipes that were assessed had been in service for approximately 24 years, and due to the concentrate and tailings (water/sand mixture) being pumped through the HDPE forcemain, there was a potential for wall loss due to internal erosion.

Figure 1. Key Map

PROJECT OVERVIEW

To evaluate the existing HDPE pipe and determine its projected life expectancy and whether the pipe breaks could be mitigated by rehabilitation, we must first consider the following list of operational parameters:

- The pumping system, including large variable speed pumps, can develop significant transient forces within the system.
- The maximum pressure for the pumping system is approximately 180 pounds per square inch (PSI) when mine tailings are being transferred to Clarabelle Mine (spikes up to 200 PSI, but generally operates between 80 and 100 PSI).
- When pumping surface water, the pressure in the main pipe generally operates between 50 and 100 PSI; water is pumped in the winter to keep the system from freezing and in the spring to manage surface drainage.
- Pumping rates generally range from 300 to 500 gallons per minute (GPM) but can reach as high as 800 GPM.
- Once the mine is closed, the drainage system will continue to operate to convey surface water off site.
- Over the past 2 years the mine experienced between 3-4 breakages per year usually during the spring when the flow rates and operating pressures are high;

- Each breakage results in a 2-day shut down and capital expenditure of $5,000 to $10,000 per repair.
- In the event of failure, the large amount of water being pumped off site has to be stored on site.

3. GENERAL APPLICATIONS OF NON-DESTRUCTIVE TESTING

Non-Destructive Testing (NDT) encompasses a wide range of analysis techniques used in science and industry to evaluate the properties of a material, component, or system without causing damage. Because NDT does not permanently alter the pipe and/or material being tested, it is a highly valuable technique that can reduce costs and save time. NDT methods are typically used where the failure of a critical component would cause significant risk or economic loss to the owner and/or environment. Vale had installed HDPE for their forcemain to transfer tailings between the mine sites for treatment and reuse. Because these connections encounter loads and fatigue during product lifetime, there is a chance that they may fail if not inspected or reviewed. Typical welding defects (lack of fusion of the weld between pipes, cracks and/or air bubbles inside the welds) could cause a structure to break or a pipeline to rupture. Reviewing the site conditions with manufacturers and third party providers caution was raised due the forcemains transferring tailings,as the tailings are highly abrasive on the inside of the pipe.

The review/evaluation of NDT techniques and products included the following:

- Ultrasonic
- Radiographic
- Remote visual inspection (RVI)
- Eddy-current testing
- Low coherence interferometry

Reviewing the above technologies with the proposed approach to determine pipe wall thickness was then limited to ultrasonic testing.

AUT was determined to be ideally suited for in-service inspection as it would avoid a costly shutdown, cleaning, and preparation of equipment for an internal inspection. Whereas other trenchless/internal inspection methods were ruled out due to the aggressive nature of the fluid within the pipe and the potential for shutdown due to limited access to the forcemain. AUT provides a full volumetric inspection and a graphical representation of the remaining pipe wall thickness. From this graph, many conclusions could be extrapolated based on knowing the installation date/service life and the operational parameters.

4. PROJECT APPLICATION OF VISUAL INSPECTION AND AUTOMATED ULTRASONIC SCANNING

Although Visual Inspection and AUT scanning is used in a variety of settings that cover a wide range of industrial activity, and applications being continuously developed, securing a company with the proper credentials and equipment to provide the information was challenging. The subcontractor we engaged needed to be flown in from Fort McMurray, Alberta, (approximately 4,000 km [2500 miles]) and access to site was limited as Operations wouldn't allow even a temporary shutdown. Furthermore, all staff needing to be on site were required to go through extensive health and safety training. All excavation also needed to be completed without extensive periods on unbury by another contractor. In essence, the execution needed to be carefully orchestrated to ensure that each activity occurred in sequential order without delay.

To complete the visual and AUT inspections, access pits were needed at four locations along the forcemain to expose the material. All bedding and cover material needed to be removed within 1 meter (m) (3 feet) of the areas and a minimum 460 mm (18 inches) of the circumference to complete the condition assessment.

A review of the existing conditions drawings indicated four key locations of sags, crests, and/or horizontal/vertical bends within the 1.6 km (1 mile) test section that was to be observed. These areas are indicated on Figure 2.

Figure 2. Test Site Locations

The AUT scanner operates on a two-axis system: X and Y. The Y-axis runs axially on the scanner arm while the X-axis runs circumferentially, utilizing its magnetic wheels. Once a stroke is complete on the Y-axis, the X-axis will index over and another Y-axis stroke will begin. Indexing increments are based on project requirements. For full volumetric coverage, indexing increments will be smaller than the transducer crystal diameter to insure an overlap in ultrasonic coverage. See Figure 3. AUT Scanning

Before the scanning starts, the AUT machine is calibrated with a test piece of HDPE to confirm test results. The machine uses the ultrasonic transducer to emit a sound wave to determine the thickness of the pipe; different frequencies can penetrate different depths. The transducer is also required to be in direct contact with the forcemain to transfer the sound wave onto/through the pipe. For our project, the contractor used water.

The transducer is then placed at the 12 o'clock position to begin reading. It then moves back and forth along the carriage to create the banding information of depth for the test section.

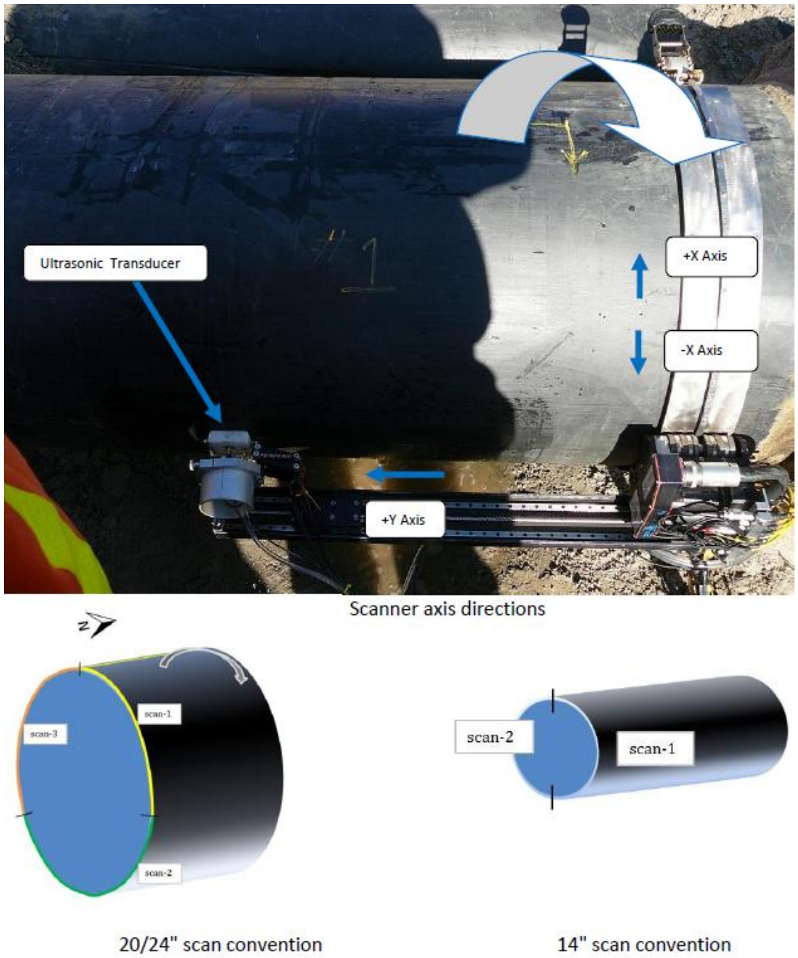


Figure 3. AUT Scanning

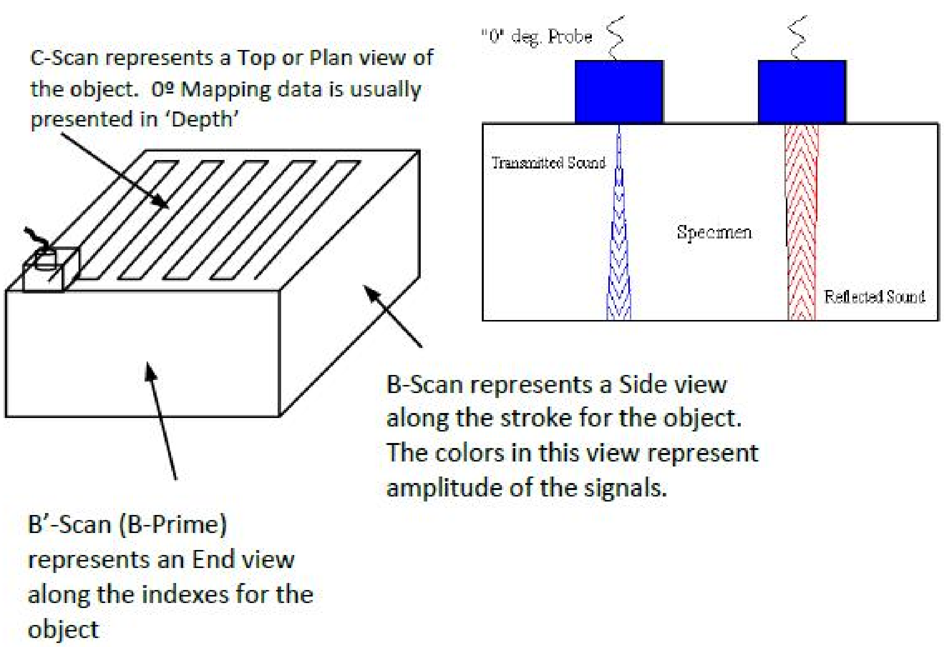


Figure 4. AUT Scanning View

The test results then are recorded in a color pallet indicating the depth/thickness of the pipe, starting at the 12 o'clock position, or in our case, 0 degrees.

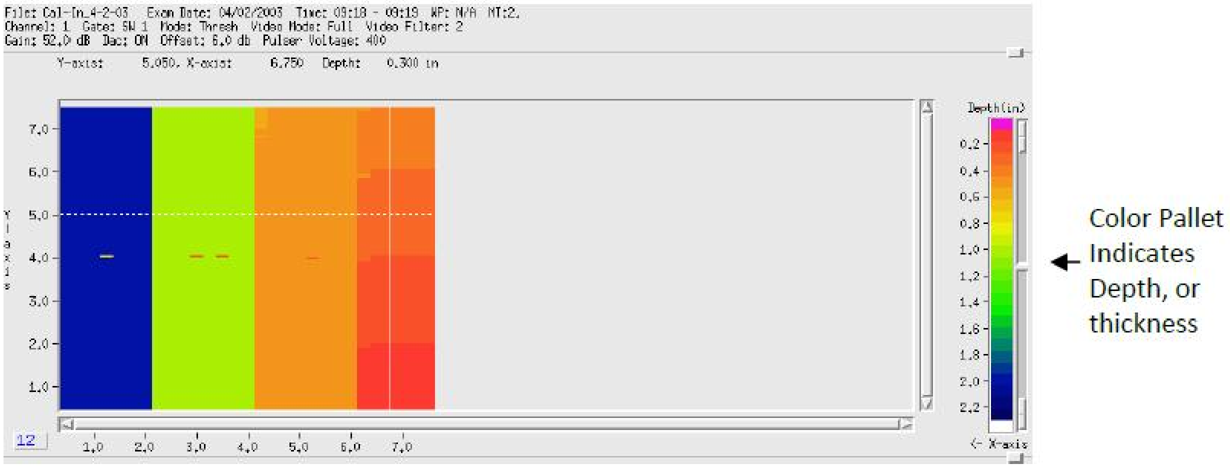


Figure 5. Example of AUT Scanning—Image Scan

5. RESULTS OF VISUAL INSPECTION AND ULTRASONIC SCANNING

AUT scanning was completed for each of the four excavation locations, and an area of the full circumference by 600mm (2 feet) length was examined by means of automated thickness measurements (Figure 2. Test Site Locations).

The AUT scanning results showed a reduction in wall thickness for both the HDPE concentrate and tailings pipelines. The reduction in wall thickness was beyond the ASTM F-714 standard set for maximum design pressure rating. The ASTM standard allows for local physical inclusion in the surface of up to 10 percent of the manufactured wall thickness. Any inclusion or loss in wall thickness greater than 10 percent should necessitate the replacement of the pipe prior to continued operations at the maximum design pressure rating. The AUT scans for the HDPE concentrate and tailings pipes show the following results:

- The 350mm (14 inch) HDPE concentrate pipe showed a wall thickness reduction in excess of 10 to 20 percent, showing a maximum reduction of approximately 5 mm.
- The 500 mm (30 inch) HDPE tailings pipe showed a wall thickness reduction for 10 to 15 percent, showing a maximum reduction of approximately 7 mm.

This reduction in wall thickness was related to erosion losses in the interior of the pipe, and as such, it was considered to be continuous along the length of the pipe.

A visual inspection for each excavation location identified the following surface inclusions:

- The 350mm(14 inch) HDPE concentrate pipe showed external scaring ranging in thickness from 1 to 8 percent of the total wall thickness.
- The 500mm (30 inch) HDPE tailings pipe showed external scaring ranging in thickness from 1 to 5 percent, and an existing repair coupling on the pipe was found in the test pit area.

The damage observed on the surface of the pipe was likely related to handling during installation. It may also have been due to handling during the completion of repairs. The presence of scaring and damage to the outer surface of the pipeline further decreases the effective pipe wall thickness and needed to be considered in combination with erosion or internal wall loss.

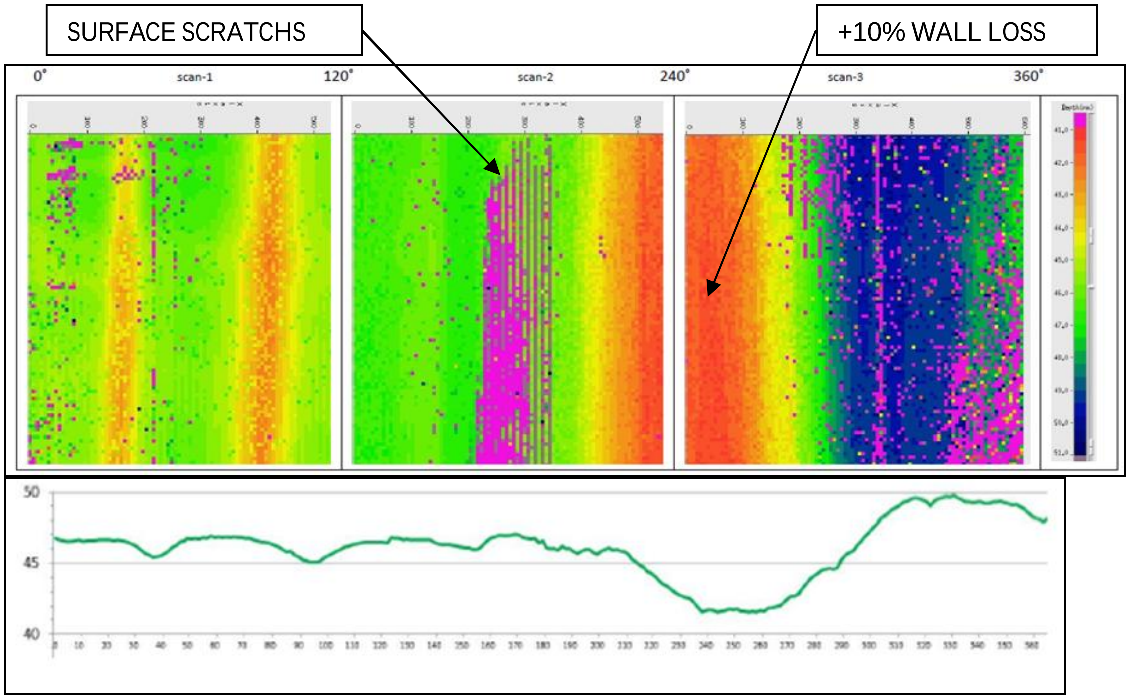
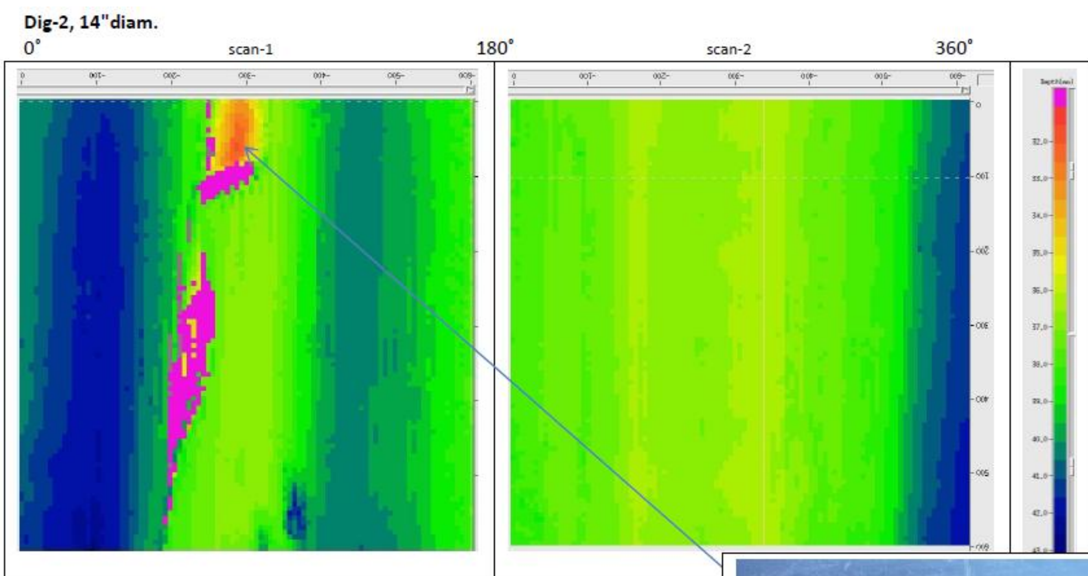


Figure 6. Scan Test Results



Remaining wt.	Scan-1 (mm.)	Scan-2 (mm.)
Min.	31.9	36.3
Max.	42.8	42.1
Mean.	39.5	37.7

Purple represents areas of no signal due to poor surface conditions, like cuts etc.

Figure 7. Test Results with Surface Deformation

6. CONCLUSIONS AND RECOMMENDATIONS

RECOMMENDATIONS

Based on the findings of the AUT scanning and visual inspections and the duration of future usage, CRA recommended that the pipelines be temporarily bypassed and replaced prior to earth grading and excavation. The general advantages for bypassing the pipe include the following:

- Safety concerns during construction can be mitigated.
- Shut-downs for cut over can be planned.
- There is little opportunity to eliminate all mechanical contact with the pipes during construction.
- Unearthing the existing pipes will place tremendous reliance on aged couplings.
- The plant is unable to accommodate extended or frequent shutdowns.
- The plant is unable to ensure low pressure ratings for extended period of time
- The costs related to the installation of new pipes are much less than the potential cost due to downtime associated with repairs.
- The most cost-effective time to replace the pipes is prior to the remedial construction.
- Environmental impacts if the pipes are not repaired may result in contamination of clean aggregate installed during the remedial construction.
- Alignment adjustments are possible.
- New access points can be considered.

CONCLUSION

Due to the existing and projected wall loss and surface inclusions into the existing pipes, the pipes are no longer capable of operating at their original maximum pressure rating of 200 PSI. Vale should consider replacement as part of the earth grading and excavation project. The primary risk during excavation will be the workers attempting to remove the bedding and backfill material away from the pipe; sudden spikes in volume (rain event) could cause transient forces that would result in separation at the repair couplings or pipe wall itself. We have also estimated that the costs related to downtime currently exceed the cost related to pipe replacement.

Due to the flexible properties of the HDPE material and short-term burst pressure rating, it is conceivable the plant can continue to operate the existing pipes at the standard operational pressure, but they will experience more frequent breaks as friction continues to degrade the wall thickness. Based on the current rate of decay, the pipes are experiencing a loss of 0.3 to 0.4 mm per year. Projected over the next 14 years, this equates to a total wall loss of approximately 4 to 5 mm. By 2028, the theoretical wall loss is calculated as follows:

- 350mm(14 inch) pipe (35mm wall) less (3 to 6mm existing wear) less (1 to 2 mm inclusions) less (3 to 4 mm future wear) equals 26 mm is equivalent to a maximum pressure rating of 160 PSI

- 500mm (30 inch) pipe (46 mm wall) less (5 to 6mm existing wear) less (1 to 2mm inclusions) less (3 to 4 mm future wear) equals 37 mm is equivalent to a maximum pressure rating of 160 PSI

The suggested reduction in maximum pressure rating can be confirmed in the HDPE material table provided by the manufacturer. The reader must confirm the remaining wall thickness in inches with reciprocal pressure rating

Although excavation for AUT scanning is necessary to expose the main on this project, municipalities can learn from the lessons of this investigation. Primarily, HDPE mains are susceptible to internal wear and should be checked as the main reaches its service design life. Inspection ports or manholes with sufficient space around the pipe should be considered as part of the capital project for future inspection.

Additional care in the stockpiling and handling of the HDPE pipe should be considered as the pipe itself is susceptible to surface damage from dragging on the ground surface during installation in both open cut and HDD.

Although the mining industry typically has more aggressive usage of the HDPE forcemain, the HDPE pipe has shown wear and loss of profile thickness, which is common with all pipes nearing 24 years of service life being used to transfer tailings. As common with all pipes, HDPE requires assessment and the consideration of future maintenance/inspection. Most designs are adequate for performing for our clients; however, in some cases maintenance/inspection points for future maintenance are sometimes excluded.

7. REFERENCES

All references should be listed and in the standard format.

Bennett, D., and Ariaratnam, S. (2008) – Horizontal Directional Drilling Good Practices Guidelines, North American Society for Trenchless Technology (NASTT), Third Edition, USA

Bennett, D., Ariaratnam, S. and Wallin, K. (2011) – Pipe Bursting Good Practices Guidelines, North American Society for Trenchless Technology (NASTT), Second Edition, USA