



"RE-BUILDING THE CITY'S WATER SYSTEMS FOR THE 21ST CENTURY"

Sewerage & Water Board OF NEW ORLEANS

January 28, 2010

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601 D Street, N.W.
Washington, D.C. 20579
DOJ Case No. 90-5-1-1-4032

Re: Sewerage and Water Board of New Orleans Modified Consent Decree – Civil Action No. 93-3212
Paragraph 43: Force Main Reliability Evaluation & Findings

Gentlemen:

Pursuant to Paragraph 43a of the Modified Consent Decree lodged on January 27, 2010, the Sewerage and Water Board of New Orleans (Board) completed the evaluation of the force mains from Pump Station A and Pump Station D to the East Bank Wastewater Treatment Plant (EBWWTP) on December 31, 2009.

Pursuant to Paragraph 43b of the Modified Consent Decree, the Board hereby submits a report of the findings for the evaluation of the force mains from Pump Station A and Pump Station D to the EBWWTP. The Board commissioned this report from a consultant at a direct cost of approximately \$1,000,000. In addition, substantial staff time has been devoted to this project.

The consultant concluded that the condition of the steel force mains is very good when considering their age and that their remaining hoop stress design life varies from 83 to 646 years. The report also makes a number of recommendations. The Board's engineers are reviewing these recommendations and will be prepared to discuss them, along with a possible implementation schedule, with EPA in the coming weeks pursuant to Paragraphs 43b and 43c of the Modified Consent Decree. With this in mind, the Board requests that EPA provide any comments on the study as soon as possible, but no later than March 26, 2010.

I certify that the information contained in or accompanying this document is true, accurate, and complete. As to those identified portions of this document for which I cannot personally verify their truth and accuracy, I certify as the official having supervisory responsibility for the persons who, acting under my direct instructions, made the verification, that this is true, accurate, and complete.

Sincerely,

Marcia A. St. Martin
Executive Director

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New Orleans, Louisiana

Sewerage & Water Board of New Orleans

Sewer Force Main Reliability Evaluation

January 2010

Sewer Force Main Reliability Evaluation Report

Prepared For

Sewerage & Water Board of New Orleans

January 2010

Prepared By

MWH, Americas, Inc.



Acknowledgments

The assistance of the Sewerage and Water Board is gratefully appreciated for providing sewerage collection system data and assisting with all site visits. In addition, we appreciate the time, efforts and guidance of the technical staff at the workshops held throughout the development of this Sewer Force Main Reliability Evaluation. Without the assistance of Marcia St. Martin, Joe Becker, Ron Spooner, Jack Huerkamp, Reid Dennis and their staffs, the task could not have been completed on schedule.

The information presented within this report reflects the efforts of the Sewerage and Water Board of New Orleans and MWH Americas, Inc.

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Executive Summary

ES.1 Purpose and Scope

This Sewer Force Main Reliability Evaluation is presented to fulfill certain requirements of the Modified Consent Decree (MCD) between the United States of America, plaintiffs-interveners, the Sewerage and Water Board of New Orleans (Board), the City of New Orleans, and the State of Louisiana. Under the terms of the MCD, the Board must evaluate the force mains from Sewer Pump Station (SPS) A and SPS D to the East Bank Wastewater Treatment Plant (EBWWTP) to “determine the current reliability of such force mains, including an examination of areas of significant weaknesses and vulnerabilities both under the Industrial Canal and within the right-of-way on land.”¹

MWH was retained to address the MCD requirements for the evaluation of the 66-/72-inch steel force main from SPS A to the EBWWTP and the 54-/60-inch steel force main from SPS D to the EBWWTP. The sewer force main (SFM) assessment includes the following tasks:

- *Subtask I.A.* – Compilation and review of pertinent historical information related to the physical and operational characteristics of the SFMs to support both the evaluation to be conducted as well as estimating levels of reliability.
- *Subtask I.B.* – Surface inspection to identify, inspect and document surface features that may be indicative of a subsurface problem (e.g., depressions, sinkholes, leaks) for the length of the SFMs exclusive of areas that are not readily accessible (e.g., the Industrial Canal crossing).
- *Subtask I.C.* – Force Main Evaluation, Sampling (Coupon Retrieval) and Testing to obtain physical pipe samples (coupons) that can be tested by a certified laboratory for the physical condition/properties of the pipe.
- *Subtask I.D.* – Report preparation to document and summarize the above activities.

This report presents the findings, conclusions and recommendations of the reliability assessment of the SFMs.

ES.2 Background

New Orleans is located in the southeastern corner of Louisiana approximately 100 miles north of the Gulf of Mexico. It sits between the east bank of the Mississippi River and the southern shore of Lake Pontchartrain. An estimated 70 percent of the City’s land is below sea level. A lack of hills and substantial barrier islands along the southern Louisiana coastline, the flat bottom of the Gulf of Mexico and the loss of wetland buffer areas make New Orleans susceptible to storm surge damage in the event of a major storm approaching from the coast.

Two such major storms inflicted substantial damage on New Orleans in recent years. Hurricane Katrina struck the Louisiana coast near Buras-Triumph. Breaches in the levees built to protect New Orleans occurred at the 17th Street Canal, the London Avenue Canal and Industrial Canal. These breaches led to flooding in nearly 80 percent of the City with water depths reaching 10 feet in some areas. Local engineers and contractors were able to temporarily repair levee

¹ U.S. Environmental Protection Agency/Department of Justice, Modified Consent Decree, Draft July 2009.

breaches and drain flood waters from New Orleans within 21 days of Hurricane Katrina's landfall.

Less than a month after Hurricane Katrina, and just days after a majority of the flood waters had been drained, Hurricane Rita made landfall between Sabine Pass, Texas, and Johnson's Bayou, Louisiana. Hurricane Rita's storm surge over-topped levees in at least three locations along the Industrial Canal, re-flooding New Orleans' Lower Ninth Ward, a few neighborhoods surrounding Lake Pontchartrain and neighboring St. Bernard Parish.

Following Hurricanes Katrina and Rita, a number of factors led the EPA to question the reliability of the SFMs from SPS A and SPS D to the EBWWTP:

- The debris- and pollutant-laden flood waters may have damaged portions of the SFMs.
- At least some of the portions of the cathodic protection system protecting the steel SFMs were destroyed.
- Evidence of material believed to be the interior lining of the SFMs was recovered at the EBWWTP screens.

Due to the immediate concerns associated with flood water damage, the Board retained Chester Engineers (Chester) to conduct a visual inspection of sewage force main rights-of-way and associated manholes in the Lakeview, Gentilly, Mid-City, Carrollton, Uptown, Central Business District, Ninth Ward, South Shore and New Orleans East areas. The results of these inspections are documented in Sewage Force Mains Assessment Post Hurricanes Katrina and Rita in 2005, Chester Engineers, November 2006. The results of the Chester evaluation are summarized in Section 2.3, Post Hurricanes Katrina and Rita Inspection. In general no significant damage to the SFMs from SPS A and SPS D to EBWWTP was noted, although substantial amounts of soil and debris were observed in many of the manholes within the sewage collection system.

The specific location for the two SFMs to be evaluated is shown in **Figure 2.1** in Section 2, Historical Information. The force main from SPS A to the EBWWTP consists of approximately 6 miles of 72-inch steel pipe constructed in 1975. Approximately 58 million gallons per day (mgd) average daily flow of wastewater is pumped through the 72-inch SFM to the EBWWTP. The 72-inch SFM begins at SPS A and generally follows local streets until reaching Interstate 10 (I-10) where it meanders in and out of the I-10 right-of-way until it turns onto Florida Avenue and passes SPS D at Peoples Avenue. The 72-inch force main then parallels the 54-/60-inch force main from SPS D along Florida Avenue. The 54-/60-inch SFM from SPS D consists of approximately 3 miles of steel pipe constructed in 1961 and 1964. Approximately 22 mgd of wastewater is pumped through the 54-/60-inch force main to the EBWWTP. The parallel SFMs along Florida Avenue then cross the Industrial Canal, continue east for a little over a mile, and then both turn north to enter the EBWWTP.

According to original construction plans for the SFMs, the pipeline was laid with 6-inches of shells and backfilled with sand to above the pipeline with wooden planks supporting the bedding material. Apparently this was done due to the low strength and high organic content of the native soils that made the soil inappropriate as a pipe bedding material.

The steel pipe material was protected from external corrosion by a coal tar enamel coating. At least some, and possibly all, the underground piping was wrapped with a fiberglass asbestos felt to protect the coal tar coating. The above ground piping and the piping going through casing

pipes were encased with a 2-inch cement mortar (gunite) coating to protect the coal tar coating. A coal tar enamel coating was applied to the interior of both SFMs to protect the steel pipe from corrosive gases present within the force mains. Additional corrosion protection was provided by a cathodic protection system including rectifier, deep ground beds and test points, additional test points on posts or in hand holes, and magnesium anodes installed at approximately 650-foot intervals along the SFM route.

The SFM route included a number of “canal” crossings. The Industrial Canal, also known as the Inner Harbor Navigation Canal and as the Intracoastal Waterway, is a controlled (locks) open channel along its route between the Mississippi River and Lake Pontchartrain. The Industrial Canal has mostly soil banks with flood protection walls and levees on both sides away from the banks. Another type of “canal” is essentially an open concrete box channel primarily designed to convey storm drainage. A third type of “canal” is a concrete channel as described above, but with a concrete top and covered (essentially similar to a long box culvert). Canal crossings of all three conditions played a major role in the routing, construction and air release facilities along the route of the two SFMs.

Initially, a large number of air bleeder valve assemblies were installed to manually bleed off air that collected during normal operation. Automatic air release valves are installed at most aerial crossings of drainage canals and at the Industrial Canal crossing for both SFMs.

ES.3 Testing Results Summary

Typically, the primary failure mode for steel force mains is internal or external corrosion, which leads to breaks or holes in the pipe wall. Large diameter steel force mains are also susceptible to collapse as well as corrosion (U.S. EPA, Condition Assessment of Wastewater Collection Systems White Paper, May 2009). Consequently, an evaluation of the SFM condition must include an analysis of the condition of the pipe walls and protective coatings. SPSs A and D, as well as the various smaller pump stations that feed into the SFMs, operate on a continuous basis and cannot be shut down for any appreciable period of time. Since this restriction precludes a visual inspection of the interior of the pipelines, a combination of non-destructive ultrasonic testing and destructive coupon extraction testing alternatives were employed. A primary goal was to minimize disturbance to the liners and SFMs, while providing a greater number of testing locations.

A testing approach to assess reliability was presented to and reviewed with Board staff on July 1, 2009. Based on input from this meeting, the testing approach was finalized and test locations were selected based on the following site criteria:

- Ease of access without traffic disturbances or permit requirements
- High risk sites (i.e., high spots such as canal crossings, levee crossings, etc.)
- Spacing, different installation contracts, and some near the Industrial Canal crossing
- Presence of possible pollutants within the areas adjacent to the SFM routes that could affect exterior corrosion
- Probability of corrosion issues
- Upstream, midpoint and downstream section data (to obtain an overall understanding of existing pipe conditions)

The selected testing program included:

- Environmental database search (to identify the potential presence of pollutants such as fuels that may accelerate coating deterioration)
- Physical visual inspection along the SFM routes (for areas of settlement, areas where the ground may be wet or have strong sewage odors indicative of leaking pipes) and, where exposed, physical inspection of the coating materials
- Hydraulic model evaluation of the interconnection of the SFMs downstream from SPS D as well as a hydraulic test of the interconnection
- Corrosion protection system inspection and soil-pipe potential testing
- Destructive coupon extraction and testing (to physically observe coating conditions and to test coating properties as well as physically measuring the wall thickness)
- Non-destructive ultrasonic testing (both at selected coupon extraction locations to calibrate ultrasonic test results in other areas of the pipelines and to assess wall thickness at various above ground locations)
- Non-destructive guided wave testing of both SFMs at the Industrial Canal (to test sections of pipe under the Industrial Canal from a single test point based on an ultrasonic pulse echo system)

The following subsections summarize the findings from each of the above testing procedures. Actual test results are contained in the following appendices:

- Appendix A – Historical Design Information
- Appendix B – Surface Inspection Photographs
- Appendix C – Soils Test Results
- Appendix D – Lining/Coating Test Results
- Appendix E – Coupon Extraction Photographs
- Appendix F – Coupon Test Results
- Appendix G – Ultrasonic Test Results
- Appendix H – Guided Wave Test Results

ES.3.1 Environmental Database Survey

Based on a search of Louisiana Department of Environmental Quality (LA DEQ) Voluntary Remediation Program (VRP), Leaking Underground Storage Tank (LUST), Underground Storage Tank (UST), U.S. EPA National Priorities List (NPL), and Resource Conservation and Recovery Act (RCRA) databases conducted in July 2009, a total of 43 sites were identified within a quarter mile of the SFM routes. The identified sites included:

- One NPL site (the Agriculture Street Landfill)
- Nine active UST facilities
- Thirty-three RCRA sites

- No VRP or LUST sites

The only reported groundwater impacts were from metals from the Agriculture Street Landfill site. No reported hydrocarbon leaks with the potential to impact soils adjacent to the steel SFM pipelines were noted.

ES.3.2 Physical Inspection

Two MWH teams walked each SFM alignment from each of the two pump stations to the treatment plant. The visual ground surface inspection found several abnormalities at the surface, including wet areas and ground subsidence. All areas were investigated with no significant problems found with either SFM.

Some maintenance issues were noted. In particular, deterioration of cement mortar coatings in several locations. The coating deterioration was most notable on the 60-inch pipe crossing the Peoples Avenue Canal. As a result of this inspection the cement mortar coating at the Peoples Avenue Canal was repaired and a new air release valve installed.

Additionally, where the pipe coatings were exposed, physical inspection of the coating materials, as well as of the surrounding soil, was completed. When exposing the pipe, a licensed asbestos abatement contractor removed the asbestos felt wrap for disposal in accordance with Louisiana Department of Environmental Quality (LDEQ) requirements.

The excavated soils ranged from “moderately corrosive” to “extremely corrosive” as defined by American Concrete Pressure Pipe Association (ACPPA). The corrosive definition conditions are driven by the low resistivity values.

The coal tar enamel exterior and interior coatings are a bitumastic based material with good pipe adhesion properties at the time of application and resilience within the mixture. The mixture was a hot applied coating that set upon cooling. The asbestos felt cloth material was also impregnated with the coal tar mixture to act as a protective barrier for the softer coal tar enamel exterior coating.

In most of the sites evaluated the lining and the coating systems are breaking down. As noted by Corrpro (Appendix D), “The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down.” However, as discussed further in Subsections ES.3.5, Destructive Coupon Testing, and ES.3.6, Non-Destructive Ultrasonic Testing, below, this deterioration of the coating material has not led to significant deterioration of the metal pipe walls. Corrpro (Appendix D) went on to note regarding the pipe, “During the visual inspection no pitting located and very minor surface corrosion present.”

Further, the “sheets of lining material” that were reported to have been recovered at the influent screens at the EBWWTP following Hurricane Katrina are unlikely to have been lining from these SFMs. The physical properties observed for the lining material suggest that the lining would be present as small flakes rather than “sheets” of lining material.

ES.3.3 Hydraulic Analysis

The 72-inch SFM from SPS A and the 54-inch SFM from SPS D to the EBWWTP are interconnected just east of SPS D, and the interconnecting valve is normally open. The potential redundancy of each SFM was evaluated in separate tests. Board personnel closed the valve shutting off the 54-inch SFM and redirected all flow from SPSs A and D through the 72-inch

SFM on April 28, 2009. A similar test was completed on June 2, 2009, when all flow from SPSs A and D was redirected through the 54-inch SFM.

The field tests indicated that both the 72- and the 54-inch SFMs could transport dry weather flows without any significant impact on pumping capacity at the two pump stations.

Hydraulic modeling was performed to further evaluate the impact of projected dry and wet weather flows on the pump stations and the SFMs. The sewer system modeling shows that under normal dry weather flow, and even under wet weather design flow, the force main system from SPS A and SPS D functions well with both force mains open from SPS D to the EBWWTP. The system is also able to convey wet weather design flow with the 54-/60-inch SFM out of service from SPS D to the EBWWTP and with all flow diverted into the 66-/72-inch SFM with all pumps operational at SPS A and SPS D. In the case of the 66-/72-inch SFM being out of service from the SPS D to the EBWWTP, the smaller 54-/60-inch SFM is able to successfully transport dry weather flow.

ES.3.4 Corrosion Protection System Testing

Both SFMs were constructed with the appropriate corrosion protection systems including sacrificial anodes and impressed current systems. Corpro inspected the existing cathodic protection facilities for these SFMs, which included the rectifiers, junction boxes and anode current outputs. Hurricanes Katrina and Rita severely damaged the impressed current systems. Only two of the seven rectifier systems are currently functional. The two functional rectifier systems are Rectifier R7, located at SPS A, 1321 Orleans Ave and Rectifier R9, located at Duels Street and Florida Boulevard.

The two functional rectifiers were tested and did not indicate the minimum criteria for cathodic protection potential according to National Association of Corrosion Engineers (NACE). Based on the potential test, all the cathodic protection potentials were indicative of the “absence of effective protection”. No sources of stray currents were identified along the SFM routes.

ES.3.5 Destructive Coupon Testing

Destructive coupon extraction consists of exposing the pipe to extract samples (coupons) for laboratory analysis of the existing pipe wall and coating thickness and condition. The analysis included a visual inspection of the coupon samples, including internal and external coating inspection and assessment, verification of pipe material, measurement of internal and external pit depth, measurement of wall thickness at multiple locations, and general corrosion evaluation. The coupon samples were tested for tensile strength, percent elongation and hardness.

Five sample locations (1C, 1D, 3A, 5A and 5B) as shown on **Figure 3.3** were evaluated by extracting physical coupons consisting of 6-inch diameter circular sections cut directly from the wall of the pipe once the bare metal had been exposed. After the metal had been exposed by scraping and abrading the coal tar enamel exterior coating, a circular metal collar, with a 6-inch pipe extension terminating in a flange, called a “weld-o-let” was welded onto the exterior of the pipe at the crown. Prior to welding, the pipe thickness in the area of the weld was tested using an ultrasonic thickness gauge to confirm the pipe material was sufficiently intact (> 0.2 inches) at the location of the weld to withstand the welding process.

After the “weld-o-let” was in place, a 6-inch flanged gate valve was bolted to the flanged end. A tapping machine was bolted to the opposite flange of the 6-inch gate valve. The gate valve was opened and the tapping machine extended a shaft fitted with a pilot drill and a hole saw to the

surface of the existing pipe. The tapping machine cut the circular coupon, approximately 6-inches in diameter, from the wall of the pipe. The shaft was retracted back behind the 6-inch gate valve along with the drill and the hole saw containing the coupon. The 6-inch gate valve was then closed, the tapping machine removed from the assembly, and the coupon retrieved.

The interior of the “weld-o-let” extension was pre-threaded to accept a rubberized threaded disk. To seal the hole left by the coupon extraction, a rubberized threaded disk was placed inside the tapping machine and the machine was reattached to the flanged extension. The rubberized, threaded disk was then screwed into the interior of the “weld-o-let”. The tapping machine was removed, the 6-inch gate valve was removed, and a blind flange was bolted onto the “weld-o-let”.

The exterior of the welded pipe assembly also was treated for corrosion resistance. The treatment specified was dependent upon whether the pipe was above or below ground.

Detailed test results are presented in Chapter 5, SFM Field Data Analysis (Table 5.3) and summarized in **Table ES.1** below. The measured thickness indicated in some cases is greater than the design wall thickness with a range of a 4.1 percent “loss” to a 2.4 percent “gain”. The ASTM A6 steel plate thickness tolerance allows for 0.01-inch below or 0.03-inch above design thickness for actual pipe manufacture. The average measured coupon thicknesses listed below that are above the design thickness are within this tolerance.

**Table ES.1
Coupon Measured Wall Thickness Summary**

Site	Design Thickness	Average Measured Coupon Thickness for 10 Measurements	Measured Thickness As A Percent of Design Thickness	Percent Variation in Thickness
1C	0.375	0.365	97.3%	- 2.7%
1D	0.500	0.496	99.2%	- 0.8%
3A	0.500	0.508	101.6%	+ 1.6%
5A	0.438	0.420	95.9%	-4.1%
5B	0.375	0.384	102.4%	+ 2.4%

ES.3.6 Non-Destructive Ultrasonic Testing

As described in a recent EPA publication,

“Ultrasonics measures the propagation time of high-frequency, short-wavelength mechanical waves through a ferrous pipe wall, and correlates this with the nominal thickness of the material. The detection of flaws is based on the reflection of the wave from the interface between materials of different properties, for instance graphite or a cement mortar lining. The resolution is such that small areas of wall loss can be identified, allowing the creation of a map of the wall thickness of a pipe. Ultrasonic waves are at frequencies greater than 100 kHz, but accurate thickness measurements use frequencies in the order of 10

MHz.” (EPA, Condition Assessment of Wastewater Collection Systems White Paper, May 2009)

Based on the testing approach, ultrasonic measurements were taken at four of the five coupon retrieval sites (1C, 1D, 3A and 5A) and eight additional sites (1A, 1B, 4A, 4B, 6A, 7A1, 7A2 and 8A). The pipeline at these sites was prepared for testing by removal of all exterior surface coatings and marking a 4-foot by 4-foot data collection area, with a 6-inch by 6-inch grid. A series of 640 data measurements (10 measurements within each grid box) were taken.

Detailed test results are presented in Chapter 5, SFM Field Data Analysis **Table 5.4** and summarized in **Table ES.2** below. As with the coupon measured thicknesses, the measured thickness indicated in some cases is greater than the design wall thickness with a range of a 6.1 percent “loss” to a 3.2 percent “gain”. The average of all the samples is only 1.0 percent less than the original design wall thickness. The ASTM A6 steel plate thickness tolerance allows for 0.01-inch below or 0.03-inch above design thickness for actual pipe manufacture. The average measured coupon thicknesses listed below are within this tolerance.

**Table ES.2
Ultrasonic Measured Wall Thickness Summary**

Site	Design Thickness	Average Measured Coupon Thickness for 10 Measurements	Measured Thickness As A Percent of Design Thickness	Percent Variation in Thickness
1A	0.375	0.373	99.5%	- 0.5%
1B	0.375	0.371	98.9%	- 1.1%
1C	0.375	0.352	93.9%	- 6.1%
1D	0.500	0.516	103.2%	+ 3.2%
3A	0.500	0.511	102.2%	+ 2.2%
4A	0.438	0.427	97.5%	-2.5%
4B	0.375	0.378	100.8%	+ 0.8%
5A	0.438	0.428	97.7%	- 2.3%
5B Side	0.375	0.377	100.5%	+ 0.5%
5B Top	0.375	0.373	99.5%	- 0.5%
6A	0.375	0.365	97.3%	-2.7%
7A.1	0.500	0.492	98.8%	-1.6%
7A.2	0.500	0.492	98.4%	- 1.6%
8A	0.375	0.365	97.3%	-2.7%

ES.3.7 Non-Destructive Guided Wave Testing

Guided wave technology (GWT) is a long-range, ultrasonic, non-destructive test developed for detecting metal loss in pipes. It is a pulse echo system designed for testing large volumes of

material from a single test point. GWT is primarily a screening tool with an aim of testing long lengths of pipe rapidly with full circumference coverage of the pipe wall. Those areas can then be evaluated further using more accurate techniques such as radiography or conventional ultrasonic inspection. The GWT is equally sensitive to metal loss on both the outside and inside surfaces of the pipe.

Two sites (2A and 2B) utilized guided wave measurements to evaluate the pipe under the Industrial Canal. GWT was completed on the 66-inch and the 54-inch pipes crossing the Industrial Canal. The work included traditional axisymmetric scans of the pipes at multiple frequencies using both longitudinal and torsional mode excitation. Phased array focusing was not possible in these scans as bends were encountered on both pipes in both directions within close proximity to the placement of the tool. Currently, phased array focusing cannot be used to enhance inspection results beyond bends.

A reasonable signal to noise ratio was obtained for the 66-inch pipe in the “backwards” direction heading west towards the Industrial Canal. Several weld-like indications were noted, and two Category 1 indications were noted. Pipe wall loss for Category 1 generally between 3 and 9 percent of the cross-sectional area. The signal was reduced in the forwards direction as the tool was placed directly behind a steel band. Therefore, the suspected confidence in this inspection is decreased. Several weld-like indications were noted.

The 54-inch pipe did not have as good a signal to noise ratio. Only half of the possible transducer modules were used due to complications with the electronics driving hardware, which most likely caused a loss of penetration power. Several weld-like indications and two Category 1 indications were noted in the backwards direction heading west towards the Industrial Canal. The quality of the scan in the forwards direction again was not as good as the tool was placed directly against the coal tar coating. A weld-like indication was noted in the forwards direction.

ES.3.8 Structural Evaluation Summary

Steel pipe wall thicknesses from both the coupon and ultrasonic measurements indicated a slight loss of wall material. The condition these steel SFMs is very good when considering their ages. Wall thickness measurements from the coupon and the ultrasonic test locations were within the range of design thickness for actual pipe manufacture. The guided wave testing results indicated only two Category 1 (least loss category) locations on both the SFM from SPS A and SPS D, and no higher loss Category 2 or 3 locations.

A reasonable approximation for the remaining life of the SFMs is to assume that the corrosion rate is linear and remains constant over the service life of the SFMs. The remaining service life could then be based on the calculated times for:

1. The point when corrosion pitting penetrates the pipe wall
2. The point when pipe wall thickness decreases such that yielding (deflection) of the pipe wall occurs under assumed loading
3. The point when the pipe wall thickness decreases such that buckling occurs under assumed pressures

The following findings were noted for each of the above calculations.

As detailed in **Table 6.2** in Section 6, Structural Evaluation Conclusions, the calculated remaining hoop stress design life varies from a number under 100 years (83 years) to a number

over 600 (646 years). These values are to be used only as condition indicators since other factors that are not included in the evaluation can significantly reduce the remaining pipe life. In general, the larger values would indicate that hoop stress is not a likely failure mode for the SFM piping and that other corrosion and or loading conditions actually may govern the life of the pipes. Some of these other conditions could include pitting (localized corrosion, which extends through the pipe), buckling, and deflection under loads. (Deflection and buckling are discussed below and pitting is not considered since it is a localized phenomenon and not a general failure mode.)

Deflection calculations are detailed in **Table 6.4**. Inversion of the “pipe can” is one definition of failure for a flexible steel pipeline; as the deflection increases, the factor of safety for pipe support decreases. At deflections greater than 5 percent, gasketed pipe joints can begin leaking, and the lining and coating can disband from the pipe. The SFM deflection calculations generally exceed 5 percent, but are not to the 20 percent range, where inversion of the pipe is possible.

A buckled pipe has the “pipe can” inverted into the center of the pipeline. This condition reduces the flow capacity significantly and can even cause failure of the pipe wall due to the sharp bends created in the pipe wall by the inversion process. Buckling can occur when a vacuum (negative surge condition) is created when the momentum of flowing liquid is reversed, such as at a check valve or following an emergency pump shut down. This reversal of flow in long flat force mains can cause the pipe to experience a complete vacuum (14.7 psi) within the pipe. Since many of the air valves are manually operated, and would normally be closed (not automatic), this analysis assumes the full vacuum condition. Based on this assumption, the buckling calculations detailed in **Table 6.6**, have a factor of safety of 1.25, which is less than the AWWA M-11 design standard factor of safety of 2.0. This is typical of large diameter pipelines installed in flat, soft soil with high groundwater conditions.

ES.3.9 Structural Conclusions

The hoop stresses in the pipe wall are very low, and the remaining pipe wall thickness is adequate for the low pressures that are applied.

The buckling factors of safety for most of the sample sites are 1.25 or less, which is less than the AWWA M-11 design standard factor of safety of 2.0. These calculations assume a full vacuum condition, since some of the existing air valves are manually operated. Converting these manual valves, and the automatic air release valves to automatic air/vacuum valves, would allow a less conservative assumption and increase the calculated factor of safety.

At deflections greater than 5 percent, the pipe lining and coating can disband. At higher deflections, the factor of safety for pipe support decreases.

As designed, these force mains had a minimum service life expectancy of 50 years or more, except for the lack of a designed-in automatic air/vacuum valves. Based on review of the limited number of samples tested, such life expectancy can be extended for many more decades, provided the automatic air release valves are modified to add vacuum capabilities (as a buckling precaution) and provided the corrosion control mechanisms are rehabilitated or replaced.

Since the findings of this evaluation are based on limited data, a detailed forensic evaluation should be performed on the section of 54-inch pipeline that is planned for relocation within the next year. The Board should formally request that the relocation contractor cooperate with the Board’s forensic investigations during their removal operations.

ES.4 Reliability Conclusions

To understand fully the condition assessment results summarized above, it is important to understand the dynamics of wastewater pipeline failure, including the level, type and severity of a failure. Failure can be:

- A sudden, catastrophic collapse of a pipe, resulting in an inability to transport wastewater
- Restricted hydraulic capacity, resulting in an inability to meet wastewater system demand
- A loss of pipe wall or joint integrity, resulting in leakage of wastewater out of the pipe

The purpose of a condition assessment is to detect pipe defects that indicate the likelihood of pipe failure, preferably prior to any given failure event. Condition assessment is particularly important in a wastewater collection system, because collection systems are typically planned, designed and installed without provision for redundancy. Conversely, water distribution systems are typically planned, designed and installed with hydraulic loops that allow water to flow to customers from another direction if one section of the water main fails.

For force mains, redundancy generally takes the form of parallel force mains from a pump station to the same, or to a nearby, discharge point. Collection system operators have historically not installed redundant force mains because:

- Force main failures have generally been an infrequent occurrence in most collection systems
- Redundant force mains may operate at lower flows that cannot carry solids and sediment loads thus causing a greater number of blockages and hydraulic capacity restrictions

With the implementation of recommended improvements and proper continued monitoring of predictive failure conditions, the SFMs are predicted to provide many years of continued reliable service.

ES.5 Recommendations

The following recommendations should be implemented for the SFMs:

1. The damaged or deteriorated corrosion control systems should be replaced or refurbished:
 - a. All rectifier installations should be replaced or repaired and allowed to operate at 75 percent of rated capacity for a minimum of two months
 - b. A close interval survey should be conducted to determine the overall protection level on the SFMs based on the refurbished rectifier impressed current system. Additional cathodic protection potential will be required due to the deterioration of the existing coating
 - c. A new sacrificial anode system should be installed to replace the destroyed anodes
2. The exposed cement mortar (gunite) coatings on canal crossings need to be inspected and repaired or replaced, as necessary.

3. All the high spots in the force mains, where curb stops/cocks or manual air release valves are or were installed, need to have automatic air/vacuum valves installed appropriately, and the existing automatic air release valves should be modified to automatic air/vacuum valves.
4. When the planned sections of the 54-inch and 72-inch force mains are replaced for the Florida Avenue Canal Improvement project, a detailed forensic evaluation of the pipe sections being removed should be performed for the following:
 - a. Areas around high spots, corporation cocks and air release valves, for signs of interior corrosion or deterioration
 - b. Any specific signs of deterioration at canal crossings
 - c. Anodes and anode connections to the pipe
 - d. Condition of welds and joints
 - e. Adherence of the linings and coatings
 - f. Bedding condition
 - g. Amount of deflection (e.g., amount “out-of-round”)
5. Since there is some redundant capability from SPS D to the EBWWTP, but currently none from SPS A to SPS D, an evaluation should be performed to see if the old 48-inch force mains to the river from SPS A and SPS D could be interconnected near the river for some level of redundancy.
6. Develop a predictive maintenance procedure for the collection system operators to maintain a SFM monitoring database, including:
 - Examination of the interior of each pipeline, including the Industrial Canal crossing, on a regular basis (every 2 to 5 years) using a leak detection technology such as the “Smart Ball” or “Sahara” systems. The initial inspection will define the baseline conditions for leak locations.
 - Maintain a database of information from SFM monitoring program including:
 - Leak location by stations
 - Locations of leak repairs
 - Pipe condition and assessment at unscheduled excavations such as utility repairs and other SFM work
 - Provide complete condition assessment on the sections of 54-inch and 72-inch SFMs to be replaced under USACE contract as discussed in item 8.2.2 of Section 8, Findings, Conclusions and Recommendations
 - Compile yearly cathodic protection system readings and maintenance reports
 - Develop a training program for operations staff defining the requirements of the database and monitoring program

- Perform stray current analysis along the pipelines on an annual basis to locate areas of changed corrosion potential
 - Document other existing or new utilities with corrosion protection systems within the area of the two SFMs that could affect the function of the SFMs cathodic protection systems
 - Link the database to any existing GIS systems to allow visual interpretation of the data
 - Perform ultrasonic thickness measurements as necessary in areas of the SFMs that experience high rates of leaks or repairs
7. Prepare a ‘Sewer Force Main Management Plan’ to capture both routine and emergency management procedures. Emergency management considerations would include:
- Working with local contractors to identify the key equipment and materials that would be needed to restore service in the event of a pipe failure
 - Develop a diversion pumping plan for each SFM. Procure and store the recommended key equipment and materials to restore and repair the SFM, and to divert flow around damaged sections during the repair operations

Installation of automatic air/vacuum valves, repairs to the corrosion protection system, and establishment of a pipe condition monitoring program for the SFMs will assist in extending the remaining service life of the SFMs and reduce future capital cost to the Board.

Section 1

Introduction

1.1 Purpose

This Sewer Force Main Reliability Evaluation is presented to fulfill certain requirements of the Modified Consent Decree (MCD) between the United States of America, plaintiffs-interveners, the Sewerage and Water Board of New Orleans (Board), the City of New Orleans, and the State of Louisiana.

Under the terms of Section XV, D. of the MCD, the Board must address the following force main reliability provisions:

- a. No later than October 31, 2009, the Board shall complete an evaluation of the force mains from Pump Station A and Pump Station D to the East Bank Wastewater Treatment Plant to determine the current reliability of such force mains, including an examination of areas of significant weaknesses and vulnerabilities both under the Industrial Canal and within the right-of-way on land.
- b. No later than 30 days following completion of the evaluation, the Board shall report its findings to EPA. Following such report, the Board shall consult with EPA on measures, if any, to be taken to address the reliability of the force mains and areas of weaknesses and vulnerabilities.
- c. If, following consultation, EPA and/or the Board determines that additional measures are necessary, no later than July 31, 2010, the Board shall submit to EPA for review and approval, in accordance with Paragraph 46, a corrective action plan and appropriate schedule for implementation of such measures. The Board shall implement the plan in accordance with the approved schedule.”¹

Preliminary investigations revealed asbestos containing material (ACM) was present and would require abatement. The Board requested, and was granted, a 60-day extension to each of the dates cited above.

This report presents the required evaluation of the sewer force mains (SFMs) transmitting flow from Sewer Pump Station (SPS) A and SPS D to the East Bank Wastewater Treatment Plant (EBWWTP). The EBWWTP is also referred to as the East Bank Sewage Treatment Plant, or EBSTP, in some references. The EBWWTP is used herein for consistency with the MCD.

1.2 Background

The City of New Orleans is located in the southeastern corner of Louisiana approximately 100 miles upstream of the Mississippi River from the Gulf of Mexico. The area of interest for this report is commonly referred to as the “East Bank.” The East Bank is located between the east bank of the Mississippi River and the southern shore of Lake Pontchartrain. An estimated 70 percent of the City’s land is below sea level. A lack of hills and substantial barrier islands along the southern Louisiana coastline, the flat bottom of the Gulf of Mexico and the loss of wetland buffer areas make New Orleans susceptible to wave, wind and rising water damages in the event of a major storm approaching from the coast.

¹ U.S. Environmental Protection Agency/Department of Justice, Modified Consent Decree, Draft July 2009.

Two major storms inflicted such damage on the City in recent years. Hurricane Katrina was the 11th named tropical storm and the 4th hurricane of the 2005 Atlantic Hurricane Season. After first striking land just north of Miami, Florida, on Thursday, August 25, 2005, Katrina struck the Louisiana coast near Buras-Triumph shortly after 6 a.m. Central Time on Monday, August 29, 2005, as a Category 4 storm. It passed within 10 to 15 miles of the City. Normally 1 foot above sea level, the water in Lake Pontchartrain peaked at 8.6 feet above sea level during the storm, according to scientists at the Louisiana State University Hurricane Center.

Breaches in the levees built to protect the City first occurred sometime between 3 p.m. and 6 p.m. Central Time on the evening of Monday, August 29, 2005. Levee breaches occurred at the 17th Street Canal, the London Avenue Canal and Industrial Canal. These breaches led to flooding in nearly 80 percent of the City with water depths reaching 10 feet in some areas. Flooding occurred in the City's Central Business District, Lakeview, Lower Ninth Ward, Carrollton, Uptown, New Orleans East and Gentilly neighborhoods. Local engineers and contractors were able to temporarily repair levee breaches and drain flood waters from the City within 21 days of the hurricane's landfall.

Less than a month after Hurricane Katrina, and just days after the City had been drained of flood waters, Hurricane Rita made landfall between Sabine Pass, Texas, and Johnson's Bayou, Louisiana, on Saturday, September 24, 2005. Initially a Category 3 storm ultimately increasing to a Category 5 storm. Hurricane Rita's storm surge over-topped levees in at least three locations along the Industrial Canal, re-flooding the City's Lower Ninth Ward, a few neighborhoods surrounding Lake Pontchartrain and neighboring St. Bernard Parish.

Following Hurricanes Katrina and Rita, a number of factors led the EPA to question the reliability of the SFMs from SPS A and SPS D to the EBWWTP:

- The debris- and pollutant-laden flood waters may have damaged portions of the SFMs.
- At least some of the portions of the cathodic protection system protecting the SFMs were destroyed.
- Evidence of material that could be from the interior lining of the SFMs was reported at the EBWWTP screens.

The Board undertook a surface inspection of the force mains to identify storm related damages.

1.3 Scope of Work

The Board authorized MWH Americas, Inc. (MWH), via a task order dated May 1, 2009, to perform this evaluation. The scope of work for that initial task order is as follows:

- *Subtask I.A.* – Compilation and review of pertinent historical information related to the physical and operational characteristics of the SFMs to support both the evaluation to be conducted as well as estimating levels of reliability.
- *Subtask I.B* – Surface inspection to identify, inspect and document surface features that may be indicative of a subsurface problem (e.g., depressions, sinkholes, leaks) for the length of the SFMs exclusive of areas that are not readily accessible (e.g., the Industrial Canal crossing).

- *Subtask I.C* – Force Main Evaluation, Sampling (Coupon Retrieval) and Testing to obtain physical pipe samples (coupons) that can be tested by a certified laboratory for the physical condition/properties of the pipe.
- *Subtask I.D.* – Report preparation to document and summarize the above activities.

This scope of work was modified by mutual agreement of the Board and MWH as follows:

- The number of coupons was reduced and this data was replaced by non-destructive testing. This was undertaken to limit the areas damaged by coupon extraction, and increase the number of test locations.
- The assessment of pipe condition at the Industrial Canal was changed from inserting a sonar survey tool to employing a strap-on guided wave tool. This was undertaken to eliminate the catastrophic risk of having to retrieve the tool and to avoid damaging the pipe to insert the tool.
- Abatement of asbestos and pipe coatings was added for each affected testing location.

1.4 Report Organization

The following briefly summarizes the contents of each chapter.

Executive Summary

The Executive Summary provides a brief stand-alone summary of this Sewer Force Main Reliability Evaluation report.

Section 1 – Introduction

This section defines the report purpose, provides an overview of the background conditions creating the need for the project, summarizing the scope of work and describing the report organizational structure.

Section 2 – Historical Information

Historical information related to the physical and operational characteristics of the SFMs is presented, including: a summary description of the force main characteristics, construction, route and summaries of previous investigations or evaluations.

Section 3 – SFM Evaluation Criteria

This section identifies the technical factors and constraints associated with a physical evaluation of the pipeline materials. Alternatives for evaluating pipes under the Industrial Canal are summarized. The section also identifies the selected test locations and methodology.

Section 4 – SFM Initial Investigations

The findings and results of these investigations are summarized, including:

- a visual inspection of the SFM route
- an environmental database review for the potential presence of hydrocarbons or other pollutant spills
- a discussion of hydraulic model results
- a hydraulic test of the interconnection of the 54-inch SFM and the 72-inch SFM downstream of SPS D

Section 5 – SFM Field Data Results

The coupon retrieval (destructive testing) locations, coupon retrieval methodology and coupon evaluation process are summarized. This section also includes the results of the ultrasonic (non-destructive) testing and the guided wave (non-destructive) testing at the Industrial Canal crossing.

Section 6 – Structural Evaluation Conclusions

The various sources of pipe wall thickness data are analyzed to select inputs for structural analysis. Structural analysis was performed using in-situ properties from the sample locations. This analysis was conducted in accordance with American Water Works Association (AWWA) M-11 – Steel Water Pipe: A Guide for Design and Installation and the American Society for Mechanical Engineering (ASME).

Section 7 – Reliability Considerations

This section describes potential failures associated with the SFMs, identifies potential environmental impacts of such failures and discusses alternatives to retain and increase reliability.

Section 8 – Findings, Conclusions and Recommendations

This section summarizes the SFM evaluation findings, conclusions and recommendations.

Appendices

The appendices contain supporting materials, data and reports documenting and summarizing the inspections and evaluations completed as part of this Sewer Force Main Reliability Evaluation.

Section 2

Historical Information

2.1 Existing Asset Data

The 54-/60-inch force main serving SPS D and the 66-/72-inch force main serving SPS A have been in operation since the mid 1960s and mid 1970s, respectively. The alignment for the SFMs is shown on **Figure 2.1** on the following page.

The preliminary sources for location and construction details are the Board's available plan, profile and as-built drawings. The Board's water and sewer location maps include references to construction contracts and construction books that correspond to each water, sewer or sewer force main project. Construction books are the Board's record of observations made by its representatives during construction of each contract. The following sources of initial construction data were identified from the work performed by Chester Engineers to conduct a visual surface inspection of force main routes after Hurricanes Katrina and Rita (Sewage Force Mains Assessment Post Hurricanes Katrina and Rita in 2005, Chester Engineers, November 2006) and supplemented by MWH. The design data reviewed as part of this study included:

- Contract 3056, Drawing 6875-S, 66-/72-inch, March 21, 1975, General Revisions May 5, 1975
- Contract 3057A, Drawing 6870-S, 66-inch, June 30, 1975, some revisions into mid-1976
- Contract 3057B, Drawing 6871-S, 66-/72-inch, some 54-inch rework, June 30, 1975
- Contract 432-S, Drawing 5984-G-8, 60-inch, April/May 1961
- Contract 472-S, Drawing 6148-G-13, 54-inch, June 1964, Revisions November 1964
- Contract 5075-1, Drawing 11404-W-27 (Partial), Relocation of 54-inch West Side Industrial Canal, March 1978, As-Builts March 1979
- Construction Book Number 3467, pages 10 to 71
- Construction Book Number 3468, pages 38 to 53
- Specifications for Contract 472-S, June 12, 1964

The following subsections summarize the asset data related to the SFMs that was available for review. A more detailed description is contained in **Appendix A, Historical Design Information**.

2.1.1 Force Main Construction Contract Documents

Contract 3056

Contract 3056 included construction of approximately 4 miles of 66-/72-inch steel, force main between SPS A and the Industrial Canal. All force mains evaluated in this project are steel. This section of the pipeline travels northwest from SPS A, then extends northeast along North Claiborne Avenue and I-10 until reaching Florida Avenue. From that point the force main runs east along Florida Avenue towards the Industrial Canal. This contract terminated at the west side of the Industrial Canal.

Figure 2.1
Force Main Network From SPS A to SPS D to East Bank WWTP

Contract 3057A

Drawings for Contract 3057A were not initially located in the Board files, but were subsequently determined from information contained in notes on the Board Location Maps 419 and 439. Contract 3057A included construction of the 72-inch and 66-inch force main. The 72-inch pipe approaches the Industrial Canal and reduces to a 66-inch diameter pipe prior to crossing under the canal. East of the canal, the 66-inch increases back to 72-inch diameter pipe. The total length of the force main constructed under Contract 3057A is estimated to total 2,950 feet in length. The pipe under the Industrial Canal has increased plate thickness (from 0.375-inches to 0.750-inches) and is buried 6- to 10-feet below the canal bottom.

Contract 3057B

Contract 3057B included construction of the 66-/72-inch force main between the Industrial Canal and the EBWWTP. This section of 72-inch pipe is located on the north side of Florida Avenue. It extends east towards the EBWWTP before the final section of the force main turns north to enter the plant site. The total length constructed under Contract 3057B is approximately 7,000 feet, or about 1.3 miles. The last 1,200 feet of the force main approaching the EBWWTP is 66-inches in diameter.

Contract 432-S

Contract 432-S included construction of the 60-inch section of force main from SPS D to Metropolitan Street along Florida Avenue. This section of the 54-/60-inch pipe has numerous street and canal crossings. The 60-inch section of force main connects to an existing 50-inch force main from SPSs 23, Chicasaw and K-Mart to the north and the combined flow goes easterly to the EBWWTP. There is a knife gate valve directly downstream of the junction of the two force mains, but there is no valve separating the two force mains.

Contract 472-S

Contract 472-S included construction of the 54-inch section of the force main from Metropolitan Street along Florida Avenue to the then existing Florida Avenue Levee crossing and then to the EBWWTP. The drawings indicate that the Industrial Canal section of the 54-inch force main was under construction via a separate contract. Although not part of this contract, the plan and profile of the pipeline design across the Industrial Canal was included on these drawings.

Contract 5075-1

Contract 5075-1 included construction of the relocation of approximately 1,000 feet of the 54-inch force main just east of the Industrial Canal and the relocation of the Florida Avenue Canal crossing. Major drainage improvements to the Florida Avenue Canal and the drainage pump station in 1978/1979 required realignment of the 54-inch force main. The original pipeline was not relocated. New facilities were designed and constructed, connected to the existing pipeline and then the old section of pipe was removed.

Construction Books

Construction Book 3467 contains information for Contracts 3056 and 3057A. Construction Book 3468 contains information for Contract 3057B. Construction Book 3467 could not be located in Board files.

The Board's Construction Book 3468 contains sketches of the pipelines and appurtenances constructed under both Contracts 3056 and 3057B.

Section 2 – Historical Information

Soils Investigations

The Board conducted a soils investigation during initial planning for the 72-inch SFM. The soils investigation results were presented in Subsoil Investigation Proposed 72-inch Diameter Sewer Force Main, Gore Engineering, Inc., March 1975, and in Subsoil Investigation, Sewerage & Water Board of New Orleans, Florida Avenue Canal Closure Tupelo Street to St. Bernard Parish Line, New Orleans, Louisiana, Gore Engineering, March 1970, with supplemental information provided in April 1975. The investigation included drilling soil test borings to determine subsurface conditions and stratification along the proposed force main alignment. Laboratory tests were performed on the samples obtained from the borings to evaluate their physical characteristics and engineering analyses were made based on the borings and test data. A total of 37 soil test bores, ranging from 30- to 40-feet below grade along the general alignment to 75-feet below grade where the force main would cross major culverts or canals, were drilled.

At depths from 5- to 20-feet below grade, the pipes would be installed in soft to very soft alluvial clays. This material was not recommended for pipe bedding due to its low strength and high organic content.

Due to the weak native soils, the pipeline was installed in trenches with a wood plank bottom with a 6-inch layer of shells and then backfilled with sand to above the pipeline. The excavation was typically supported with wood sheets that were left in place.

The only information in the Gore soils reports with regards to corrosion potential are the notes on the presence of groundwater or moisture and the identification of clayey organic soils that were present in varying degrees throughout the SFM route.

Construction Details Summary

Contract documents from these construction projects specified use of steel plate conforming to American Society of Testing Materials (ASTM) A-283, American Petroleum Institute API-5L, Grade B for fabricating these pipes. The thickness used varied by diameter and location as shown in **Table 2.1**.

Table 2.1
General Pipe Wall Thickness Summary

From	To	Pipe Diameter ¹ (inches)	Pipe Wall Thickness (inches)
SPS A	Industrial Canal	72	0.375
West side of Industrial Canal	East side of Industrial Canal	66	0.750 ²
Industrial Canal	EBWWTP	72	0.375
SPS D	Rail Road at France Street	60	0.375
West side of Rail Road	East side of Rail Road	60	0.500
Rail Road at France Street	Florida Avenue Canal	60	0.375
West side of Florida Avenue Canal	West side of Industrial Canal	60	0.500
West side of Industrial Canal	East Side of Industrial Canal	60	0.750 ³
East side of Industrial Canal	EBWWTP	60	0.375

¹ Other localized variations occur which are not included in this general summary.

² With a 2-inch exterior concrete coating.

³ With a 2.5-inch exterior concrete coating.

These pipes were all specified to provide coal tar enamel coating on the interior and exterior surfaces. An asphaltic felt wrapping material was applied to the pipe to an indeterminate portion of the SFMs. A 2-inch concrete coating was applied over all other coatings where the pipes are above grade. This typically occurs at canal or levee crossings and entering or exiting pump stations or treatment processes.

These pipes and fittings were constructed with single full fillet welded joints in most locations. While there are no push-on-joints used, some bell and spigot joints were used with dual fillet welding, and some joint restraint systems or gaskets were included in this work. Where the pipes were installed through the marsh, just south of the EBWWTP, the joints are double full fillet welded.

Pipe Installation

The majority of the SFMs are installed in Board-controlled rights-of-way with no appreciable surface loading. These pipes typically have 5-foot of cover and air release valves at local high points. Crossings at surface roads are subject to traffic loads. Crossings at rail roads are provided with a casing pipe to sustain the applied loads. The condition and adequacy of casing pipes were not evaluated in this project.

The SFMs bridge open drainage canals with support from two, or more, pile supported bents. The SFMs cross under the Industrial Canal as it is a navigable waterway. Air release valves are provided upstream and downstream of these crossing to bleed accumulated gases from these localized high points.

The native soils are classified as “corrosive” to “extremely corrosive,” a condition not corrected by the use of select backfill. A corrosion protection system consisting of impressed currents and sacrificial anodes was installed throughout the SFMs.

Air Release Mechanisms

The SFMs have air release mechanisms, both manual and automatic, at high points within the system. The list of air release mechanisms, their location and type are shown in **Table 2.2**.

**Table 2.2
Summary of Air Release Mechanisms**

Pipe Information/Location	Valve Type	Valve Description
66-/72-inch SFM crossing levee to EBWWTP	Manually Operated Air Release	2" Corp. Stop
54-/60-inch SFM crossing levee to EBWWTP	Manually Operated Air Release	2" Corp. Stop
54-/60-inch SFM crossing Florida Ave. Canal south of EBWWTP	Manually Operated Air Release	2" Corp. Stop
66-/72-inch SFM at east side of Industrial Canal	Automatic Air Release	2" Val-Matic, Model No. 48 B.W.A. 150 psi
54-/60-inch SFM at east side of Industrial Canal	Manually Operated Air Release	2" Corp. Stop
66-/72-inch SFM crossing Florida Ave. Canal	Automatic Air Release	2" APCO, Model No. 200
54-/60-inch SFM crossing Florida Ave. Canal	Manually Operated Air Release	2" Corp. Stop
66-/72-inch SFM crossing Peoples Ave. Canal	Automatic Air Release	2" APCO, Model No. 200
54-/60-inch SFM crossing Peoples Ave. Canal	Automatic Air Release	Val-Matic Combination Air/Vacuum Valve
66-/72-inch SFM crossing Florida Ave. Canal west of Almonaster Ave.	Automatic Air Release	2" APCO, Model No. 200

2.1.2 Sewer Pump Station Data

The Pump Station Testing and Evaluation Report, August 1997 (Exhibit 7 of the Consent Decree), describes each of the 66 pump stations then operated and maintained by the Board along with an assessment of their condition and performance. SPS A and SPS D are two of the key stations within the sewer system. The following description of SPS A and SPS D are from the Corrective Action Plan for the East Bank Wastewater Collection System, MWH Americas, Inc., July 2000.

Sewer Pump Station A

SPS A is a large regional pumping station that conveys all of the flow from the Carrollton, Uptown, Central Business District (CBD) and Mid-City basins. It contains six pumps of which only two usually operate in combination during dry weather. Two vertical shaft pumps are powered by 1,250 horsepower (hp) motors, while four horizontal shaft pumps are powered by two 2,300 hp motors (two pumps powered by each motor).

As noted in the Corrective Action Plan for the East Bank Wastewater Collection System pre-Katrina report, SPS A re-pumps flow from Stations 1, 3, 5, 6, 8 14 and 15 in addition to its own 7.4 square mile service area. This equates to an overall contributing service area of approximately 19.8 square miles. During dry weather, SPS A pumped approximately 58 mgd in pre-Katrina flows. Of this amount, approximately 21 mgd was contributed by the SPS A service

Section 2 – Historical Information

area and the remaining 37 mgd was re-pumped flow from the other stations. SPS A pumps all of its flow directly to the EBWWTP through the 72-inch SFM.

Sewer Pump Station D

SPS D, like SPS A, is a large regional pump station that conveys most of the flow from the Lakeview and Gentilly basins. It contains three pumps of which only one normally operates during dry weather. The single vertical shaft pump, normally operated alone during dry weather, is powered by a 275 hp motor. Two horizontal shaft pumps are powered by a single 2,500 hp motor on a common shaft.

As noted in the Corrective Action Plan for the East Bank Wastewater Collection System pre-Katrina report, in addition to its own 2.1 square mile service area, SPS D re-pumps flow from Stations 4, 9, 17, 18, 19, 20, 21, 22, Lakewood South and City Park. This equates to an overall contributing service area of approximately 16.3 square miles. During dry weather SPS D pumped approximately 22 mgd in pre-Katrina flows. Of this amount, approximately 3 mgd was contributed by the SPS D service area and the remaining 19 mgd was re-pumped flow from the other stations. SPS D pumps all of its flow directly to the EBWWTP through the 54-/60-inch SFM. The 54-inch SFM interconnects with the 72-inch SFM from SPS A just downstream of SPS D. The interconnecting valve is normally open.

Sewer Force Main System Summary

The force mains evaluated in this project are a critical component of the sewer system for the City's East Bank. The SFMs convey the majority of flow serving a significant portion of the sewer system as shown in **Table 2.3**.

Table 2.3
Service Overview for East Bank Sewer System

Asset	Service Area (square miles)	Percent of Service Area (%)	Pre-Katrina Dry Weather Flow (mgd)	Percent of Flow (%)
SPS A	7.4	9.4	21	19.8
SPS A Re-pump	12.4	15.8	37	34.9
SPS D	2.1	2.7	3	2.8
SPS D Re-pump	14.2	18.1	19	17.9
All others	42.4	54.0	26	24.6
East Bank Totals	78.5	100.0	106	100.0

2.2 Operation and Maintenance Data

As a part of the Board's normal operation and maintenance (O&M) activities, maintenance staff respond to all reports of suspected problems with the SFMs. The Board implemented CassWorks®, the computerized maintenance management system (CMMS), in 1998 to generate and track work orders. The CassWorks® database was reviewed to identify work orders associated with these SFMs.

CassWorks® does not include a separate classification for force mains. Rather, most of the useful information relative to force mains is included in the "comments" section of the work

order. Consequently, computerized data queries are difficult and it is not certain that all relevant work order records were retrieved. Work orders from 1998 through 2008 were queried and none were associated with the SFM pipelines. A number of work orders were noted in conjunction with preventive maintenance activities for the manual operation of the air release valves and corporation stops.

Interviews with the Board's maintenance staff indicated that there have not been leaks on the SFMs. No leaks were identified from the queries completed as part of this study. The maintenance staff noted that none of the repairs involved the SFMs, but were associated with the air valves or access flanges.

The Board uses external vendors to maintain the corrosion protection facilities. Since 1999 the vendor has been Corrpro Companies, Inc. (Corrpro). Corrpro provided quarterly surveys of the impressed current and sacrificial anode cathodic protection system. The quarterly surveys included inspections of rectifiers, junction boxes and anode current outputs at the 47 cathodic protection sites. The inspections also included identification of required repairs or material replacement needs. Pre-Katrina, several of the sites required such repairs or replacements on an occasional basis. Corrpro or another vendor would complete the identified repair or replacement upon issuance of a work order by the Board. The surveys continued through 2008, but none have been conducted in 2009. Post-Katrina, Corrpro has identified portions of the corrosion protection system that are out-of-service. The problems are described in more detail in Section 5, SFM Field Data Analysis, but include disconnected cables, failed power supplies and total system destruction.

2.3 Post-Hurricanes Katrina and Rita Inspection

Due to the immediate concerns associated with flood water damage following Hurricanes Katrina and Rita, the Board retained Chester Engineers, Inc., (Chester) to conduct a visual inspection of each of the sewage force main rights-of-way and associated manholes in the Lakeview, Gentilly, Mid-City, Carrollton, Uptown, Central Business District, Ninth Ward, South Shore and New Orleans East areas. The results of these inspections are documented in Sewage Force Mains Assessment Post Hurricanes Katrina and Rita in 2005, Chester Engineers, November 2006. The Chester surface inspection found no significant damage to the SFMs from SPS A and SPS D to EBWWTP. Substantial soil and debris was observed in many of the manholes. Manholes needing to be cleaned were spray painted orange with the letter "C" on the lid.

Section 3

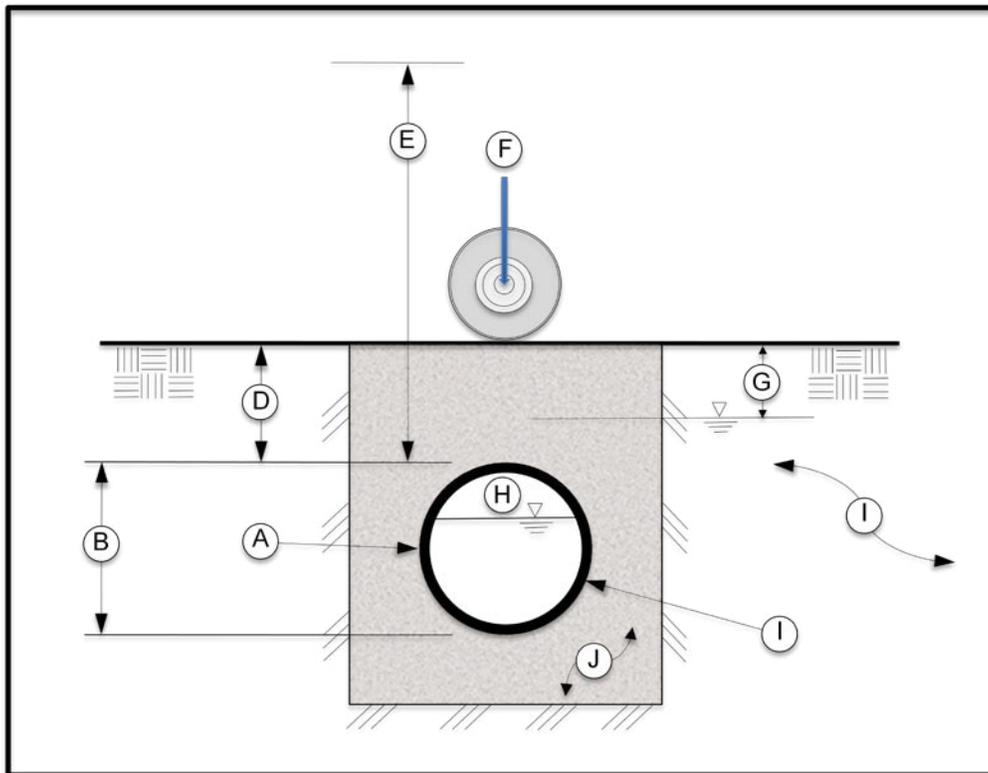
SFM Evaluation Criteria

3.1 Criteria Identification

The objective of this project is to quantify the reliability of the SFMs. This will be accomplished by estimating the remaining life based on an industry standard analysis method. The AWWA Standard M-11, “Steel Water Pipe: A Guide for Design and Installation” was selected for this project. This standard is a well-tested, conservative standard with a long history of acceptance in the municipal water and wastewater industry. Further, the standard is well-suited to the expected quantity and quality of data being obtained.

The predictive capability of even such a proven analytical method is entirely dependent upon the representative value of input data. Thus, reasonable criteria for selecting and obtaining input data is fundamental to the validity of any conclusions or recommendations. The primary inputs to the evaluation are: pipe thickness, pipe material properties, applied loads and soil properties. These parameters are shown in **Figure 3.1** below. Other inputs are based on known values (e.g., pipe diameter) or are constants selected based on good professional judgment. The overall intent is to provide conservative estimates of remaining service life and identify approaches to mitigate factors that unacceptably reduce the remaining life of the SFMs.

Figure 3.1
Pipeline Evaluation Parameters



Section 3 – SFM Evaluation Criteria

<u>Item</u>	<u>Required Data</u>	<u>Data Source</u>
A - Pipewall	<ul style="list-style-type: none"> - Design, or Nominal, Thickness - Remaining Thickness - Material Properties - Coating Condition/Adhesion 	<ul style="list-style-type: none"> • Project Records • Caliper and Ultrasonic Thickness testing of Coupons and In Situ Pipe Material • Laboratory Testing of Coupons • Field Measurements and Data
B – Outside Diameter	<ul style="list-style-type: none"> - Design, or Nominal, Diameter 	<ul style="list-style-type: none"> • Project Records
C – Native Soils	<ul style="list-style-type: none"> - Structural Properties - Corrosion Potential 	<ul style="list-style-type: none"> • Project Records • Project Records and Field Data
D – Depth of Cover	<ul style="list-style-type: none"> - Soil Unit Weight and Depth 	<ul style="list-style-type: none"> • Project Records
E – Pressure Loads	<ul style="list-style-type: none"> - Normal Operation - Vacuum 	<ul style="list-style-type: none"> • Modeling and Field Data • Assume Full Vacuum
F – Imposed Loads	<ul style="list-style-type: none"> - Wheel Loads at Roads 	<ul style="list-style-type: none"> • H-2O Loading Assumed
G – Depth of Groundwater	<ul style="list-style-type: none"> - Unit Weight of Water and Depth 	<ul style="list-style-type: none"> • Field Data
H – Gas Pockets	<ul style="list-style-type: none"> - Potential Source of Internal Corrosion 	<ul style="list-style-type: none"> • Project Records
I – Electrolytic Corrosion	<ul style="list-style-type: none"> - Potential for Pipe Loss Due to Electrolysis with Soil 	<ul style="list-style-type: none"> • Field Data
J – Trench Backfill	<ul style="list-style-type: none"> - In Combination with Item C, Native Soils, Provides Support to Side Wall of Pipe to Resists Applied Loads 	<ul style="list-style-type: none"> • Project Records

The evaluations prepared for this project are based upon a rationally selected, but widely spaced sample set. The amount of pipe sampled by all methods will represent less than one percent of the total volume of the pipe in the scope of this project. This approach is reasonable given the degree to which the conditions of service for these pipes are known. The intent is to use this data to produce conservative predictions, but shorter or longer estimates of remaining life could easily result from taking more samples or selecting other sites. As additional data becomes available through other efforts, that data should be reviewed to determine if material changes in remaining service life are predicted. Finally, this work product is the output of an engineering evaluation of the expected conditions of service. There are other conditions that can affect remaining life and are beyond the scope of this project. Examples could include right-of-way encroachments that impose new loads on the pipe, nearby excavations that reduce support of the pipe wall or inadvertent strikes by trenchless utility installation.

3.2 Evaluation Criteria

In the context of this project the pipe is considered reliable until it no longer meets the applicable criteria of AWWA M-11. The three criteria are for failure by bursting (hoop strength), buckling (rapid collapse from imposed loads) and deflection (long term loss of water tightness due to imposed loads). Analytical methods for each of these criteria have parameters that are set by the analyst based on good engineering judgment, prescribed by the standard, fixed with respect to time and changing (or able to change) with respect to time. Each of these parameters is estimated based on design conditions, field observations and sampling/testing.

Parameters that generally are not changing with respect to time include soil corrosivity, soil strength, traffic loads and properties of the pipe material. Each of these are validated, but do not play a role in changing the remaining service life. Parameters that are subject to change include pipe wall thickness and pressure or vacuum loads. Pipe wall thickness is the critical parameter for estimating remaining service life. For each of the three criteria there is a critical thickness of pipewall below which the criteria are not satisfied. The relationship between design, measured, and critical thickness with respect to remaining service life is shown in **Figure 3.2** on the following page. As a result, significant effort is planned to obtain a representative distribution of samples upon which to estimate current and projected values. Pressure and vacuum loads are a result of how the SFMs are operated and maintained. These values can rise or fall based on usage, but for the purpose of this analysis, are based on current operating conditions.

Data is also collected to aid in understanding the overall system, but is not a direct input to the analysis under AWWA M-11. The condition of the coating systems (interior and exterior) and the status of the cathodic protection systems are key examples. These observations help to define potential responses to the analytical outputs.

The criteria for estimating remaining service life do not address leaks. Leaks are generally a maintenance issue that can be addressed without significant interruption in service. The AWWA M-11 standard does not predict any aspect of leak distribution or occurrence. Leaks are a serious issue and should be viewed as a leading indicator of pipeline condition. Portions of the field work were targeted on visual detection of surface indications of leaks.

3.3 Force Main Assessment

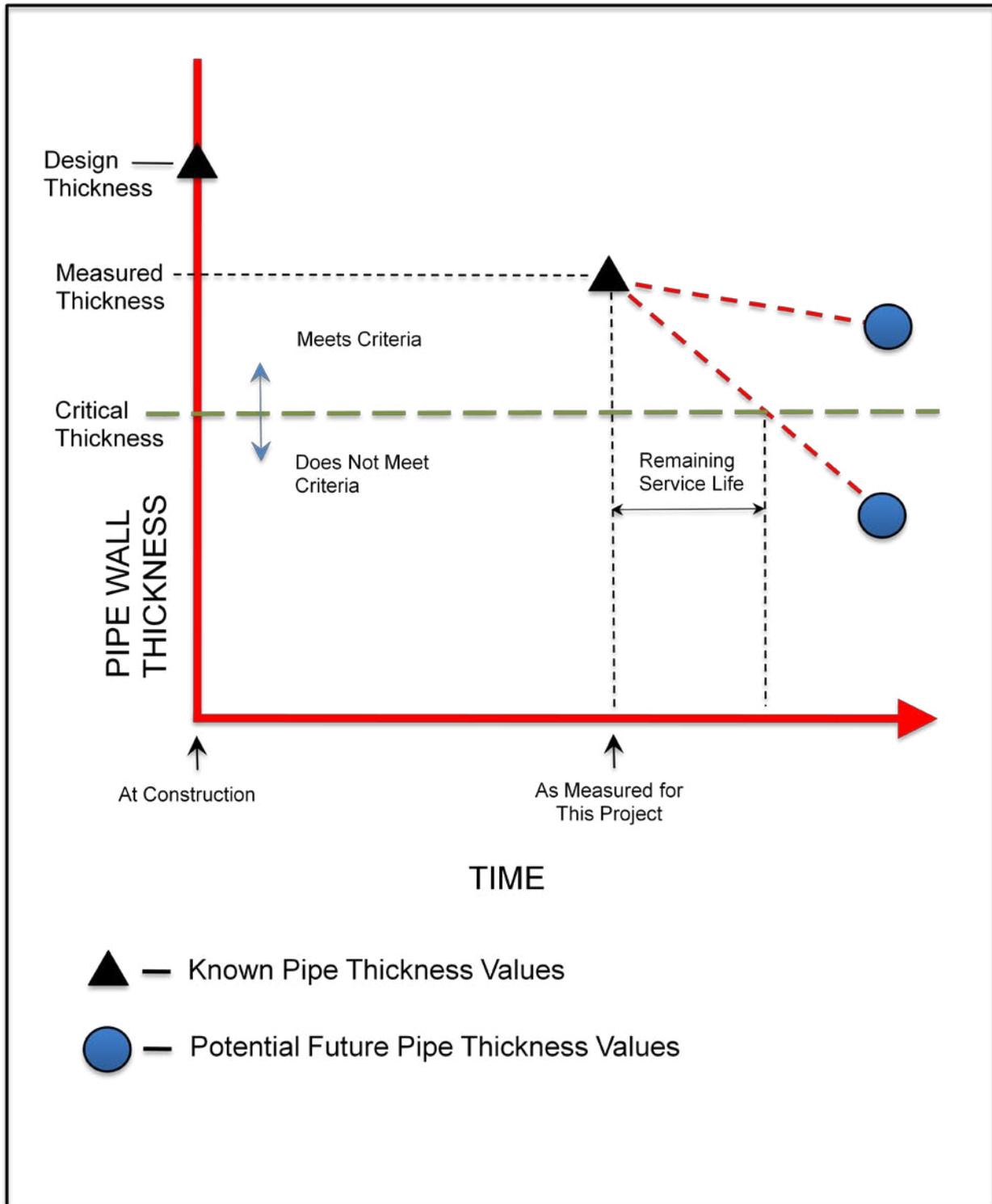
Force mains are infrequently inspected in detail because of the need to interrupt service and because of the limited number of inspection technologies suitable for use in pressurized pipes. (Condition Assessment of Wastewater Collection Systems White Paper, U.S. EPA, May 2009)

A complete visual inspection of the total length of the SFMs is not feasible due to lack of access and the impacts of interrupting service. Consequently the condition assessments include a combination of surface observation of the entire alignment and uncovering the pipes at discrete locations to obtain data for quantitative analysis.

3.4 Initial Investigations

The initial field investigations are intended to identify locations where pipe failures may be present, assess the feasibility of taking direct samples and measurements from the pipe, and observe changes from the original design documents. This work is conducted principally through visual observation of surface features. These observations were made by experienced engineers,

Figure 3.2
Relationship Between Design, Measured, and Critical Pipewall Thickness



Section 3 – SFM Evaluation Criteria

inspectors, testing laboratory technicians, contractors and Board staff. During this initial investigation, the existing hydraulic model was rerun to estimate pressure conditions.

The SFMs are primarily underground, but are exposed at above ground canal crossings and flood wall penetrations where the physical condition can be visually inspected. Visual inspection can indicate areas where the pipe protective coatings have been damaged or are in deteriorating condition. Similar observations can be made at access manholes. A surface inspection of the SFM alignments can also provide visual indications of potential problems with the underground portions of the pipelines. Possible leaks, pipe sags or significant pipe deflection may be seen at the surface as pools of water or ground depressions. Areas of high susceptibility to corrosion of the steel pipe walls can also be identified along the SFM alignments. External corrosion is accelerated in areas with high organic soils and the presence of hydrocarbons from such things as petroleum leaks near the SFMs. The potential for such fuel releases or other pollutant spills are identified by searching environmental reporting databases. The right-of-way is also checked to confirm that no additional loads are present. These could include temporary debris piles or encroachments by new construction.

In addition to the above physical inspections, hydraulic conditions can be evaluated using the existing hydraulic model. Hydraulic models are used to simulate conditions for various wastewater flows and can provide valuable indications of pressures and flow rates. Limited field testing of the interconnection of the SFMs downstream of SPS D can also be performed by changing existing valve settings for the interconnecting pipes.

The initial investigation tasks selected for this project include the following activities:

- A visual inspection of the exposed, above ground sections of the SFMs to
 - Evaluate existing coating condition
- A visual surface inspection of the SFM alignments to:
 - Identify areas of ground settlement
 - Identify areas where the ground is wet
 - Identify areas where there is a strong raw sewage odor
 - Identify encroachment of the right-of-way
- A visual inspection of access manholes to:
 - Identify signs of external corrosion on the pipelines, air release valves or access flanges
 - Identify possible damages to the pipelines, valves or access manholes
- An environmental database search to define areas of potential fuel or other pollutant releases within one-quarter mile of the alignment
- A hydraulic conditions evaluation based on:
 - Hydraulic modeling runs
 - Physical testing of the SFM interconnection downstream of SPS D to evaluate capacity impacts of removing force mains from service

The results of the above listed initial inspections tasks are presented in Section 4, SFM Initial Investigations.

3.5 Structural Testing

The majority of data required to determine whether the criteria of AWWA M-11 are met can only be obtained by direct access to the pipe and its surrounding soil. SPSs A and D operate 24-hours per day and cannot be shut down long enough to drain and access the interior of the pipe. Thus, all data about interior condition is derived from coupons removed from the pipe wall in service or from indirect thickness measurements. The following subsections describe the selected testing alternatives and test site locations.

3.5.1 Testing Alternatives

A combination of non-destructive ultrasonic testing and destructive coupon extraction testing was developed to provide the required data. A primary goal of the testing plan was to minimize the damage to pipe walls and coating while capturing representative testing locations.

The following techniques were included in the testing plan.

1. *Ultrasonic testing.* This is a non-destructive ultrasonic test to measure pipe wall thickness at discrete points. It requires direct access to the pipe wall, but does not damage the pipe or interior coating. The exterior coating is restored upon completion of the testing. This technique allows a large area of pipe (e.g., 4-foot by 4-foot) to be measured. It is also performed in advance of coupon extraction to confirm the pipe wall is thick enough to support that operation.
2. *Guided wave assessment.* A guided wave assessment technique was used at the Industrial Canal crossing. Guided wave technology (GWT) is a non-destructive ultrasonic test using a pulse echo system. This technique maps pipe wall thickness for the full pipe circumference for some distance on either side of the tool. This distance varies with site specific geometry and construction details. GWT is primarily a screening tool with an aim of rapidly testing long lengths of pipe. Those areas can then be further evaluated with greater accuracy using other techniques such a radiography or conventional ultrasonic inspection.
3. *Coupon extraction and testing.* Destructive coupon extraction consists of exposing the pipe to extract 6-inch coupons for laboratory analysis of the existing pipe wall and coating thickness. The analysis includes a visual inspection of the coupon samples, including internal and external coating inspection and assessment, verification of pipe material, measurement of internal and external pit depth, and measurement of wall thickness at multiple locations. The coupon samples are also be tested for tensile strength, percent elongation and hardness.
4. *Cathodic protection potentials.* As explained in the National Association of Corrosion Engineers International (NACE) Basic Corrosion Course Handbook, “In a corrosion cell, electrons flow through a metallic path from sites where anodic reactions are occurring to sites where they allow cathodic reactions to occur. Ions (charged particles) flow through the electrolyte to balance the flow of electrons. Anions (negatively charged ions from cathodic reactions) flow toward the anode and cations (positively charged ions from the anode itself) flow toward the cathode. The anode corrodes and the cathode does not.

There is a voltage, or potential, difference between the anode and the cathode that can be measured.” Cathodic protection potential measurements will be obtained at each accessible site on the SFMs by a NACE certified Cathodic Protection Tester using a calibrated, high impedance digital multimeter and a saturated Cu/CuSO₄ reference electrode. Efforts will also be made to identify foreign sources of stray currents such as other cathodic protection systems, direct current transit systems and ship yards or welding shops.

5. *Coating condition.* The exterior coating is visually observed and subjected to bond strength testing. This information is used to assess the likely value these coatings provide for corrosion protection.

3.5.2 Test Locations Selection

The location of test sites was developed to provide data that reflects:

- The major construction contracts
- Good spatial distribution to capture upstream, midpoint and downstream reaches
- High points that may be subject to gas accumulation and thus to internal corrosion from hydrogen sulfide (Note: Soils along the entire alignment are characterized as “corrosive” to “extremely corrosive” and thus all buried locations are considered suitably representative of this condition.)
- Sites with particular vulnerability such as exposed canal crossings or the buried crossing at the Industrial Canal

The specific locations for testing were then established by reviewing access factors such as:

- Traffic control and inconvenience to adjacent commercial or residential interests
- Logistical supply requirements for test apparatus
- Permit requirements and timing
- Overall cost of work and site restoration

An initial list of proposed locations for the ultrasonic (non-destructive) testing and for the coupon retrieval (destructive) testing was prepared based on evaluation of the construction drawings, field visits along the force main routes, photographs, and the criteria listed above.

Table 3.1 provides a list of the sites selected for field testing.

**Table 3.1
Evaluation Test Locations**

Location	Test Site	Pipe Size (inches)	Test Method
EBWWTP at Levee	1A	66	Ultrasonic Thickness Measurements
EBWWTP at Levee	1B	54	Ultrasonic Thickness Measurements
EBWWTP	1C	66	Coupon and Ultrasonic Thickness Measurements
EBWWTP	1D	54	Coupon and Ultrasonic Thickness Measurements
East Bank of Industrial Canal	2A	66	Guided Wave Thickness Measurements
East Bank of Industrial Canal	2B	54	Guided Wave Thickness Measurements
West Bank of Industrial Canal	3A	54	Coupon and Ultrasonic Thickness Measurements
Florida Ave. Canal Crossing	4A	72	Ultrasonic Thickness Measurements
Florida Ave. Canal Crossing	4B	54	Ultrasonic Thickness Measurements
Peoples Ave. Canal Crossing	5A	72	Coupon and Ultrasonic Thickness Measurements
Peoples Ave. Canal Crossing	5B	60	Coupon Thickness Measurements
Sewer SPS D Yard	6A	60	Ultrasonic Thickness Measurements
St. Bernard Avenue	7A1	48	Ultrasonic Thickness Measurements
St. Bernard Avenue	7A2	48	Ultrasonic Thickness Measurements
Frenchmen Street	8A	72	Ultrasonic Thickness Measurements

Based on the available plans **Table 3.2** on the following page was prepared to alert field crews as to expected conditions at the proposed testing/sampling locations. It should be noted that the initial pipe found at test Site 1D on the EBWWTP site was concrete pipe rather than the anticipated steel pipe. The initial test location was relocated to an existing valve box on the 54-inch pipe where a coupon was extracted and ultrasonic thickness measurements were performed. **Figure 3.1** (after Table 3.2) shows the test locations along the two SFM routes.

While not clearly delineated on the construction drawings, the Specifications for Contract 472-S (for the 54-inch SFM) clearly calls for the installation of “Fibrous Glass Material and Bonded Asbestos Felt Wrap.” Due to the potentially hazardous nature of the wrapping materials, samples were collected to test for the presence of asbestos. These tests proved positive and appropriate measures were taken to abate the asbestos-containing materials during all of the work conducted as part of this project.

Table 3.2
Test Location Expected Conditions ¹

Test Location ²	Contract Number	Drawing Number	Station	Distance from SPS A (feet)	Distance from SPS D (feet)	Pipe Size (inch)	Wall Thickness (inches)	E (psi)	72-inch SFM		54-inch SFM		72-inch SFM		54-inch SFM	
									HGL at Avg. Flow (feet)	Working Pressure at Avg. Flow (psi)	HGL at Avg. Flow (feet)	Working Pressure at Avg. Flow (psi)	HGL at Peak Flow (feet)	Working Pressure at Peak Flow (psi)	HGL at Peak Flow (feet)	Working Pressure at Peak Flow (psi)
1A – 66" NDT at EBWWTP Levee	3057-B	11 of 16	81+93	29,600	N/A	66	0.375	Above grade	32.7	14.2	N/A	N/A	33.7	14.6	N/A	N/A
1B – 54" NDT at EBWWTP Levee	ND	ND	ND	N/A	16,200	54	0.375	Above grade	N/A	n/a	31.5	13.7	n/a	n/a	33.0	14.3
1C – 66" Coupon at EBWWTP	ND	ND	ND	30,500	N/A	66	0.375	200	29.3	12.7	n/a	n/a	29.3	12.7	n/a	n/a
1D – 54" Coupon at EBWWTP	ND	ND	ND	N/A	17,423	54	0.500	200	N/A	n/a	29.1	12.6	n/a	n/a	29.1	12.6
2A – 66" GW at E.B. Ind. Canal	6870-S	9 of 14	8+80	22,357	N/A	66	0.375	Above grade	47.0	20.4	n/a	n/a	50.0	21.7	n/a	n/a
2B – 54" GW at E.B. Ind. Canal	472-S	7 of 19	59+22	N/A	8,545	54	0.500	Above grade	n/a	n/a	48.8	21.1	n/a	n/a	52.0	22.5
3A – 54" Coupon at W.B. Ind. Canal	472-S	6 of 19	51+20	N/A	7,760	54	0.500	Above grade	n/a	n/a	51.4	22.3	n/a	n/a	55.3	24.0
4A – 72" NDT at Florida Ave. Canal	6875-S	40 of 53	129+82 ³	19,644	N/A	72	0.438	Above grade	56.2	24.4	n/a	n/a	61.5	26.7	n/a	n/a
4B – 54" NDT at Florida Ave. Canal	472-S	6 of 19	49+00	N/A	6,700	54	0.375	Above grade	n/a	n/a	54.5	23.6	n/a	n/a	58.5	25.4
5A – 72" Coupon at Peoples Ave. Canal	6875-S	30 of 53	79+25	14,280	N/A	72	0.438	Above grade	68.3	29.6	n/a	n/a	75.8	32.8	n/a	n/a
5B – 60" Coupon at Peoples Ave. Canal	432-S	2 of 9	20+00	N/A	560	60	0.375	Above grade	n/a	n/a	68.3	29.6	n/a	n/a	75.9	32.9
6A – 60" NDT at SPS D Yard	432-S	2 of 9	23+60	N/A	305	60	0.375	200	n/a	n/a	69.2	30.0	n/a	n/a	77.5	33.6
7A – 48" NDT at St. Bernard Ave	6875-S	12 of 53	54+75	4,880	n/a	48	0.500	200	94.0	40.7	n/a	n/a	98.0	42.5	n/a	n/a
8A – 72" NDT at Frenchmen St.	6875-S	18 of 53	87+00	N/A	8,460	72	0.375	200	82.0	35.5	n/a	n/a	88.5	38.4	n/a	n/a

¹ Not applicable = N/A. Not available = NA. No data = ND. Beyond the model = BM.

² Non-destructive test = NDT. Guided wave test = GW.

³ Offset approximately 160 feet.

**Figure 3.3
SFM Testing Location Map**

Section 4

SFM Initial Investigations

4.1 General

As noted in Section 3, SFM Evaluation Criteria, the SFM condition assessment was conducted in two components:

- Initial investigations
- Structural testing

This section presents the results of the initial investigations condition assessment component. Subsection 4.2 describes the visual inspection of the ground surface and above ground portions of the pipelines. Subsection 4.3 summarizes the results of the environmental database search. Subsection 4.4 presents hydraulic model results. Subsection 4.5 presents the results of a physical hydraulic test of operating with a single SFM interconnection downstream of SPS D.

4.2 Surface Inspection Findings

During this SFM reliability evaluation, visual inspections were performed along the entire alignment of the SFMs on June 16, 17 and 18, 2009. The inspection was focused on identifying features that may influence the pipeline condition such as sources of stray currents, loads not shown on the construction drawings, and other surface features that may indicate changes in the pipeline performance. The teams looked for areas of soil subsidence above or around the pipe, running water, wet ground or raw sewage odors. They visually investigated manholes to see if surface corrosion was present on the pipeline or if any air release valves or access flanges showed signs of damage or excessive corrosion. The exterior coating condition of the above ground, exposed sections of the pipelines were also inspected for signs of damage or deterioration. The visual inspections also noted the location of manholes, valves (both manual and automatic relief), canal crossing locations and wall penetrations.

Deterioration of cement mortar coatings was noted in the above ground locations. The location of cement mortar deterioration was on the upstream side of the 60-inch crossing at the Peoples Avenue Canal. As shown in **Photograph 4.1** on the following page, the cement mortar coating is broken and displaced. The damage was repaired by the Board as part of restoring the pipe after coupon removal. **Photograph 4.2** shows the repaired cement mortar coating of the 60-inch crossing at Peoples Avenue Canal. Two “wet areas” were observed along the SFM alignments. One of the wet areas with ponded water was determined to be a water main leak. Another wet area was noted near where the 72-inch SFM crosses the 54-inch SFM. This leak was on the 4-inch discharge pipe for the manual air release valve and not on the SFM pipe wall. This leak was repaired. Four surface depressions or “sink holes” were noted along the SFM alignments as shown in **Photographs 4.3** through **4.6**. None of these depressions exhibited running water and each is being investigated further by the Board to better understand the cause. Maintenance issues such as displaced frames and covers on access manholes as shown in **Photograph 4.7** and the potentially buried access manhole in **Photograph 4.8** were also noted.



Photograph 4.1
Peoples Avenue Canal Crossing Coating Deterioration



Photograph 4.2
Peoples Avenue Canal Crossing Repaired



Photograph 4.3
Soil Subsidence Near 54-Inch SFM Along Florida Avenue Near Reynes Street



Photograph 4.4
Soil Subsidence Near 72-Inch SFM Across From 3211½ Shell Street



**Photograph 4.5
Soil Subsidence Near 54-Inch SFM**



**Photograph 4.6
Soil Subsidence Near 60-Inch SFM Crossing Under Storm Sewer (Shown)**

Section 4 – SFM Initial Investigations



Photograph 4.7
Access MH on 72-Inch SFM



Photograph 4.8
Not Found Access MH on 72-Inch SFM

These observations confirm those by Chester and do not indicate any locations where failure has occurred.

4.3 Environmental Database Search

The exterior surface of the pipe was provided with a coal tar epoxy coating overlain with a fabric wrap. The coal tar epoxy provides a barrier to corrosion and the fabric wrap protects the coal tar from abrasion damage. The value of this coating system is wholly dependent upon its integrity. Coal tar epoxy, while stable when exposed to most ground waters, is subject to decomposition when exposed to petroleum products (e.g. fuel spills). Regulatory databases were queried to identify the potential for fuel, or other pollutant, spills within a quarter of a mile of the SFM alignments.

The Louisiana Department of Environmental Quality (LA DEQ) Voluntary Remediation Program (VRP), Leaking Underground Storage Tank (LUST), Underground Storage Tank (UST), United States Environmental Protection Agency (US EPA) National Priorities List (NPL), and Resource Conservation and Recovery Act (RCRA) databases were all researched. The results are summarized in **Table 4.1**.

Table 4.1
Petroleum Spill Research Summary

Database	Result
Voluntary Remediation Program	No reported sites
Leaking Underground Storage Tank	No reported sites
Underground Storage Tank	Nine active sites with none related to petroleum products
National Priorities List	One site (Agricultural Street Landfill) with no groundwater impacts from petroleum products
Resource Conservation and Recovery Act	Thirty-three sites with none related to petroleum products

Based on these findings, degradation of the coal tar epoxy coating is not likely to have resulted from exposure to petroleum products.

4.4 Hydraulic Model Evaluation

The key gravity mains and the Board's entire force main system, including these key force mains, are included in the Board's hydraulic model. Several hydraulic model runs were performed on SPS A, SPS D and the two SFMs to support this project. The two SFMs are interconnected near SPS D. There is also a knife valve in the 54-/60-inch SFM downstream of the junction a 50-inch force main entering from the north via Metropolitan Street. This valve allows the 50-inch force main to be routed through the 66-/72-inch SFM should downstream problems exist within the 54-/60-inch SFM.

Section 4 – SFM Initial Investigations

The hydraulic modeling simulated both dry and wet weather flows. These flows were routed through the SFMs with the SFMs interconnected and with all flow routed through just one of the SFMs (i.e., operating with one SFM out-of-service downstream of SPS D). Model runs consisted of 6 basic operating scenarios (under all scenarios the interconnecting valve between the two SFMs is open):

1. Existing System using pre-Katrina Dry Weather Flows (Scenario name = *ex1dwf4b*, or existing 1 times dry weather flows run 4b).
2. Existing System using pre-Katrina Wet Weather Flows, equivalent to double the pre-Katrina dry weather flows (Scenario name = *ex2dwf1b*, or existing 2 times dry weather flows run 1b).
3. Existing System with 54-/60-inch SFM shut off downstream of SPS D and all flow routed via the 66-/72-inch SFM using pre-Katrina Dry Weather Flows (Scenario name = *ex1dwf72*, or existing 1 times dry weather flows routed through the 72-inch SFM)
4. Existing System with 54-/60-inch SFM shut off downstream of SPS D and all flow routed via the 66-/72-inch SFM using pre-Katrina Wet Weather Flows (Scenario name = *ex2dwf72*, existing 2 times dry weather flows routed through the 72-inch SFM).
5. Existing System with 66-/72-inch SFM shut off downstream of SPS D and all flow routed via the 54-/60-inch SFM using pre-Katrina Dry Weather Flows (Scenario name = *ex1dwf54*, or existing 1 time dry weather flows routed through the 54-inch SFM).
6. Existing System with 66-/72-inch SFM shut off downstream of SPS D and all flow routed via 54-/60-inch SFM using pre-Katrina Wet Weather Flows (Scenario name = *ex2dwf54*, or existing 2 times dry weather flows routed through the 54-inch SFM).

The profile for the 54-inch SFM from SPS D to the EBWWTP in black (the bottom line) and the hydraulic grade lines (HGLs) for the following scenarios are shown on **Figure 4.1**.

- Scenario 1 in blue (the lowest HGL), with pre-Katrina dry weather flows (DWFs) of approximately 40 mgd divided between the two SFMs, the normal configuration.
- Scenario 2 in purple (the middle HGL), with pre-Katrina wet weather flows of 50 to 65 mgd divided between the two SFMs, the normal configuration.
- Scenario 5 in orange (the highest HGL), with pre-Katrina DWFs of approximately 70 mgd routed solely in the 54-inch SFM (the valve on the 72-inch SFM closed), an alternate configuration.

The profile for the 72-inch SFM from SPS A to the EBWWTP in black (the bottom line) and the hydraulic grade lines (HGLs) for the following scenarios are shown on **Figure 4.2** (follows Figure 4.1).

- Scenario 1 in orange (the lowest HGL), with pre-Katrina dry weather flows (DWFs) of 65 to 70 mgd divided between the two SFMs, the normal configuration.
- Scenario 3 in blue (the next highest HGL), with pre-Katrina DWFs of 85 to 96 mgd routed solely in the 72-inch SFM (the valve on the 54-inch SFM closed), an alternate configuration.

Figure 4.1
54-/60-Inch SFM Profile for Scenarios 1, 2 and 5

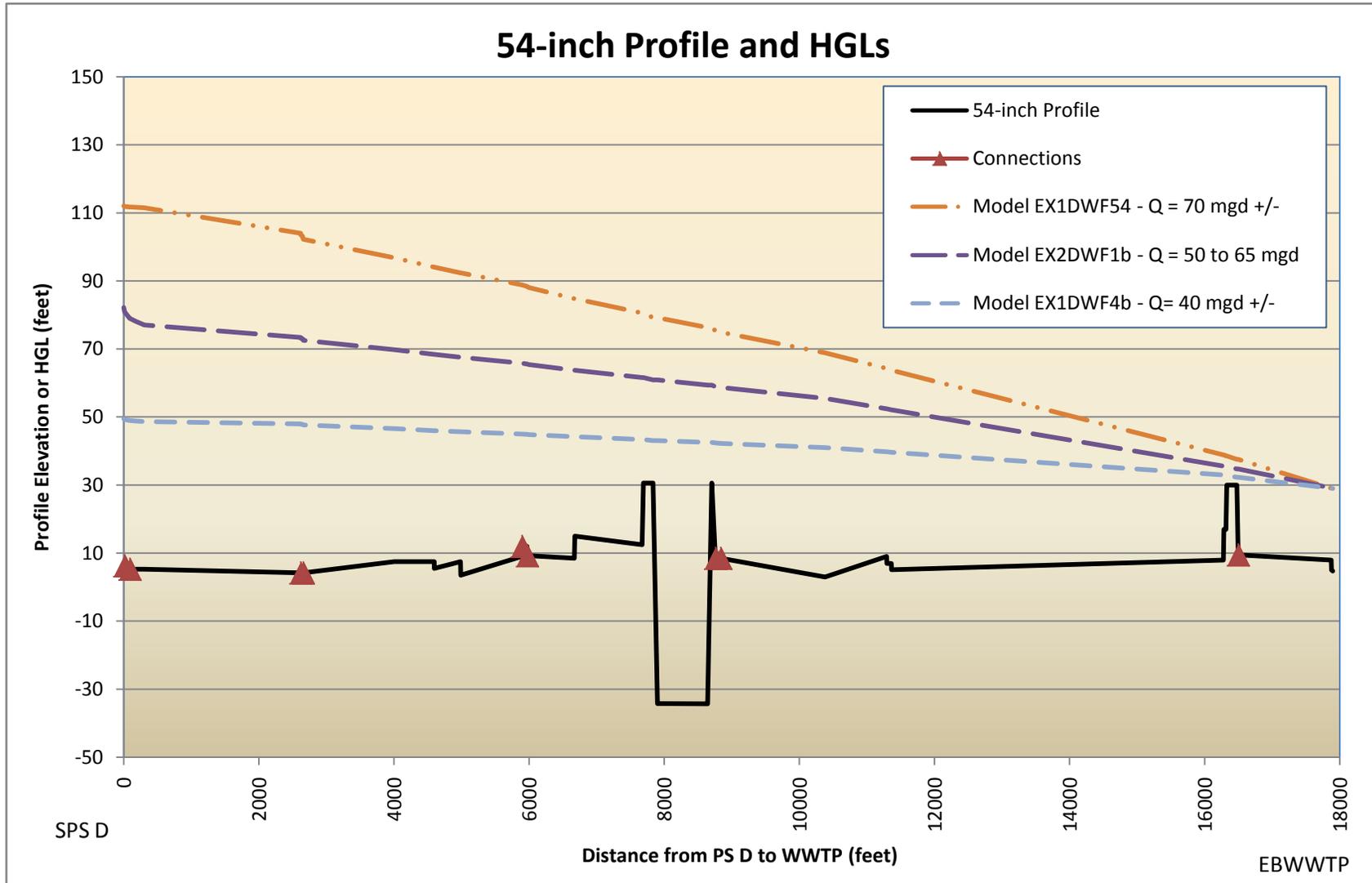
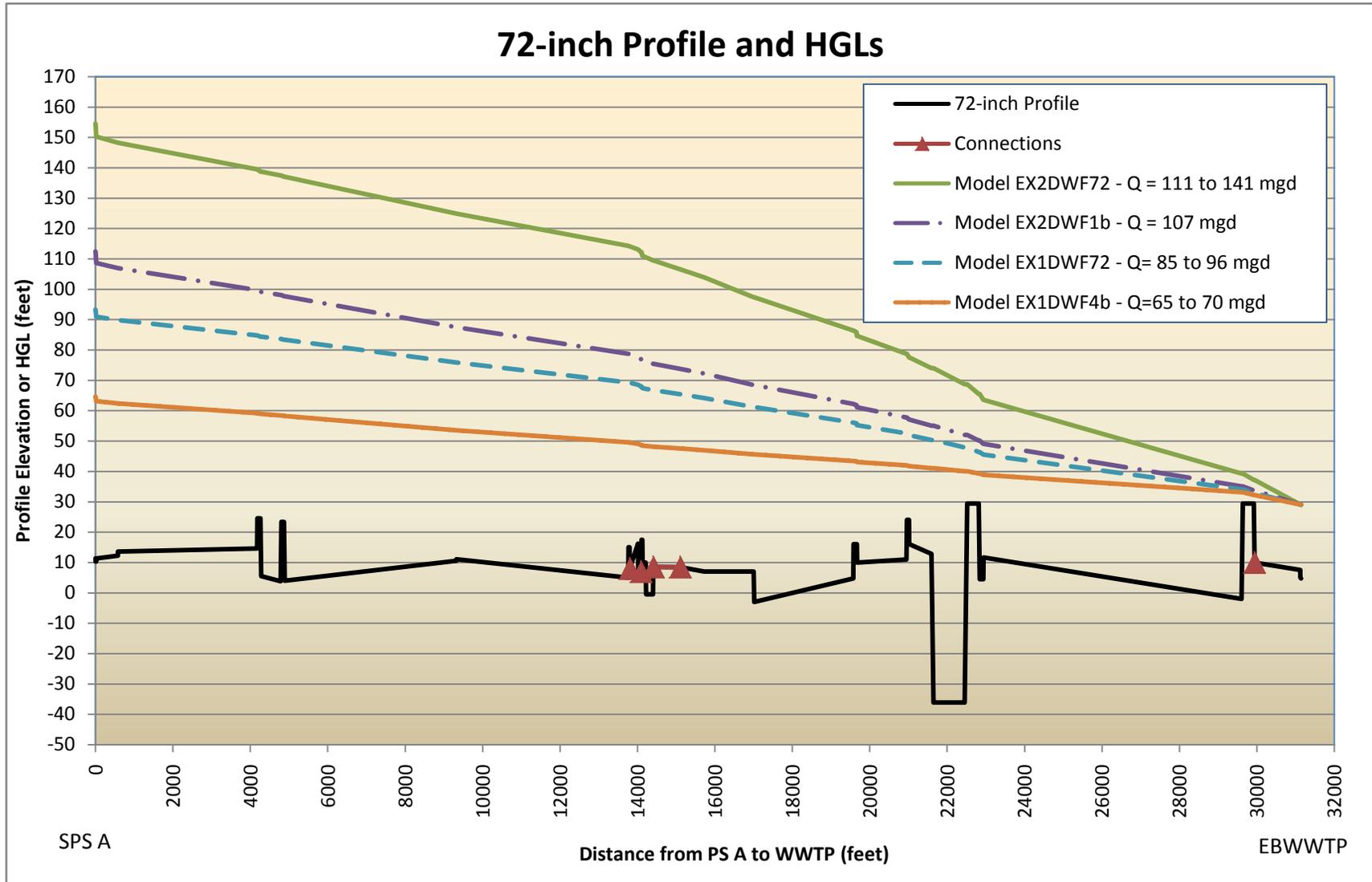


Figure 4.2
66-/72-Inch SFM Profile for Scenarios 1, 2, 3 and 4



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- Scenario 2 in purple (the next highest HGL), with pre-Katrina wet weather flows of approximately 107 mgd divided between the two SFMs, the normal configuration.
- Scenario 4 in green (the highest HGL), with pre-Katrina wet weather flows of 111 to 141 mgd routed solely in the 72-inch SFM (the valve on the 54-inch SFM closed), an alternate configuration.

The current modeling of the SFMs shows that under dry weather and wet weather design flows, the force mains from SPS A and SPS D function well in the normal configuration. The system is also able to convey wet weather design flows with the 54-/60-inch SFM out of service from SPS D to the EBWWTP using only the 66-/72-inch SFM with all pumps operational at SPS A and SPS D. When the 66-/72-inch SFM is out of service from SPS D to the EBWWTP, the 54-/60-inch SFM is also able to successfully convey dry weather flow to the EBWWTP. The hydraulic model failed to reach a solution for Scenario 6. The model-predicted pressure shown in Figures 4.1 and 4.2 were used as the inputs for structural analysis of the SFMs at each sample or test location.

4.5 Flow Diversion Test

The Board conducted tests to observe dry weather performance with a single SFM operating downstream of SPS D.

On April 28, 2009, all flow was routed through the 72-inch SFM between SPS D and the EBWWTP. This condition was sustained with acceptable performance (i.e., wet well levels and pressures were in normal ranges) from 10 a.m. to 6 p.m. The test confirmed that all necessary valves are functional and flow in the range of 50 to 55 mgd can be maintained for about eight hours.

On June 2, 2009, all flow was routed through the 54-inch SFM between SPS D and the EBWWTP. This operating condition was only maintained for six hours and was terminated due to presence of wet weather flows. The test confirmed that all necessary valves are operational and flow can be maintained in the range of 40 to 60 mgd.

Section 5

SFM Field Data Analysis

5.1 General

As described in Section 3.4, Structural Testing, eight independent sites were selected for data collection on the SFMs. One of the sites had two sample locations (7A1 and 7A2). All of the testing was performed by, or for, Corrpro Companies, Inc. (Corrpro). Site excavation and preparation, was performed by Boh Brothers, Inc. (Boh). Ultrasonic thickness measurements were performed by Non-Destructive & Visual Inspection, LLC, (NVI) under the direction of Corrpro. Guided wave testing was performed by FBS, Inc., (FBS) under the direction of Corrpro.

The results for the test evaluation process are included in the following appendices:

- Appendix B – Surface Inspection Photographs
- Appendix C – Soils Test Results
- Appendix D – Lining/Coating Test Results
- Appendix E – Coupon Extraction Photographs
- Appendix F – Coupon Test Results
- Appendix G – Ultrasonic Test Results
- Appendix H – Guided Wave Test Results

Each of these testing processes and the accompanying results are discussed in further detail in the following subsections. Section 5.2 contains the test preparation procedures. Section 5.3 contains both the destructive and non-destructive test results.

5.2 Test Preparation

An assessment of the two SFMs is necessary to determine the existing condition of the pipelines and to develop a reasonable assumption for remaining service life. It is not possible to perform a detailed inspection of the total length of each pipeline. Thus a program to conduct physical inspections and tests at key locations along each pipeline was developed to provide data to support this evaluation.

The first part of the testing program consists of a visual inspection of the route of each force main. The results of this visual inspection were presented in Section 4, SFM Initial Investigations. Additional physical inspections were conducted at selected sites by exposing the buried pipes as well as physical inspections of the cathodic protection system. The preparation required for these physical inspections are described below with the results presented in Section 5.3, Testing Results.

The second part of the testing program consists of destructive and non-destructive testing at eight locations. This testing includes the collection of coupons, physical samples taken from the pipe wall, and ultrasonic thickness testing of the pipe wall. The results of these testing programs are presented in Section 5.3, Testing Results.

The pipes crossing under the Industrial Canal are infeasible to access for either visual inspection or collection of coupons. Consequently the third part of the testing program consists of a non-destructive test method called “guided wave technology” (GWT) that allows for testing lengths

of pipeline from a single test location. The GWT was performed at the Industrial Canal crossings. The GWT results are also presented in Section 5.3, Testing Results.

All three testing methods provide specific data on the current physical condition of the pipelines that can be used to calculate the present strength and to estimate the remaining service life. These calculations and remaining service life estimates are presented in Section 6, Structural Evaluation Conclusions.

The following subsections describe the preparation procedures for each of the three types of tests.

5.2.1 Physical Inspection

Obtaining access for visual inspection and testing required uncovering of the pipe in all locations. These pipes are either buried, encased in a mortar protective layer, covered with a coating system or some combination of each. The basic steps taken to access the pipe for each condition are as follows:

- **Exposed Buried Pipe.** Pipes were machine excavated to the spring line of the pipe. Side support was re-established by placing all backfill in accordance with Board standard repair procedures. The ground surface was then restored to match existing conditions.
- **Mortar Coating.** The mortar protective layer was saw cut to a uniform line at the limits of the work zone. The mortar was removed by fracturing and restored.
- **Coating Systems.** A licensed, asbestos abatement contractor removed the asbestos containing felt wrap and disposed of the material all in accordance with LDEQ regulations. The coal tar enamel coating was removed by scraping and abrading to expose the pipe as required for each type of test. All exposed pipe, including welding sites, was re-coated to inhibit corrosion.

The results of the below ground inspection and testing is detailed in Section 5.3, Testing Results.

5.2.2 Cathodic Protection System Inspection

As part of the physical testing program, Corrpro inspected the cathodic protection facilities for these SFMs. This inspection was similar to the quarterly survey of the 47 cathodic installation sites performed under the Board's annual maintenance contract. This included inspection of rectifiers, junction boxes and anode current outputs.

In addition to the physical inspection, cathodic protection potentials were obtained on each accessible site. A Corrpro NACE certified Cathodic Protection Tester obtained calibrated, high impedance digital multimeter readings using a saturated Cu/CuSO₄ reference electrode. The potential readings were obtained at the pipe to soil/water interface to minimize infrared (IR) error.

The results of the cathodic protection system inspection and potential testing are detailed in Subsection 5.3.2, Cathodic Protection System Test Results.

5.2.3 Destructive Coupon and Non-Destructive Ultrasonic Testing

The sample locations and test types are listed in **Table 5.1**. Photographs of the sites are contained in **Appendix B Surface Inspection Photographs**.

Coupon Extraction

There are five locations where coupons were extracted from the pipelines. The coupons are 6-inch diameter circular sections that are cut directly from the wall of the pipe. Once the surface of the pipe was prepared as described above, a circular collar called a “weld-o-let” was welded onto the pipe at the crown. Prior to welding, the pipe thickness in the area of the weld was tested using an ultrasonic thickness gauge to confirm the pipe material was sufficiently intact to withstand coupon extraction. Installation of the collar proceeded if the existing pipe wall thickness was greater than 0.2-inches at the location of the weld. None of the locations had a wall thickness less than 0.2-inches.

A length of 6-inch pipe terminating in a flange was attached to the welding collar. After the welding collar was in place, a 6-inch gate valve was bolted to the flange. A tapping machine was bolted to the 6-inch gate valve. The gate valve was opened, the tapping machine extended a shaft fitted with a pilot drill and a hole saw to the surface of the pipe. After cutting the coupon, the shaft was retracted back behind the 6-inch gate valve. The 6-inch gate valve was then closed, the tapping machine removed, and the coupon retrieved.

The interior of the “weld-o-let” fitting is threaded to accept a rubberized plug. Prior to removal of the tapping machine, a rubberized, threaded disk was screwed into the “wel-o-let” to provide a seal. The tapping machine was removed, the 6-inch gate valve was removed, and a blind flange was bolted onto the welded pipe assembly.

Coupons were sent to LeHigh Testing Laboratories, Inc., for testing. A minimum of ten wall thickness tests were performed for each coupon as well as depth measurements of internal and external corrosion pits. Physical properties of the steel were also analyzed for each coupon including tensile strength, percent elongation and hardness evaluation.

Ultrasonic Preparation

As described in a recent EPA publication,

“Ultrasonics measures the propagation time of high-frequency, short-wavelength mechanical waves through a ferrous pipe wall, and correlates this with the nominal thickness of the material. The detection of flaws is based on the reflection of the wave from the interface between materials of different properties, for instance graphite or a cement mortar lining. The resolution is such that small areas of wall loss can be identified, allowing the creation of a map of the wall thickness of a pipe. Ultrasonic waves are at frequencies greater than 100 kHz, but accurate thickness measurements use frequencies in the order of 10 MHz.” (EPA, Condition Assessment of Wastewater Collection Systems White Paper, May 2009)

Four of the five coupon retrieval points were examined using ultrasonic testing to determine pipe wall thickness. However, all five coupon sites were marked with a grid for ultrasonic testing. The 4-foot by 4-foot area was further divided into a 6-inch by 6-inch grid. The grid was defined by an alpha and numeric reference system labeling the rows and columns of the matrix. Typically 10 data measurements were taken within each grid box, for a total of 640 measurements at each location.

Section 5 – SFM Field Data Analysis

**Table 5.1
Test Location and Type**

Test Designation ¹	Test Location	Type of Test
1A – 66" NDT	66-inch pipeline from SPS A at the interior face of the flood control levee north of Florida Avenue.	Non-Destructive Testing using ultrasonic thickness gauge – Above Grade
1B – 54" NDT	54-inch pipeline from SPS D at the interior face of the flood control levee north of Florida Avenue.	Non-Destructive Testing using ultrasonic thickness gauge – Above Grade
1C – 66" Coupon	66-inch influent piping from SPS A in the plant yard at the EBWWTP.	Physical Coupon Extraction – Below Grade
1D – 54" Coupon	54-inch influent piping from SPS D in the plant yard at the EBWWTP.	Physical Coupon Extraction – In Valve Box
2A – 54" GW	66-inch pipeline from SPS A on the exterior side of the east flood protection wall at the Industrial Canal.	Non-Destructive Testing using Guided Wave Technology – Above Grade
2B – 54" GW	54-inch pipeline from SPS D on the exterior side of the east flood protection wall at the Industrial Canal.	Non-Destructive Testing using Guided Wave Technology – Above Grade
3A – 54" Coupon	54-inch pipeline from SPS D on the exterior side of the west flood protection wall at the Industrial Canal.	Physical Coupon Extraction – Above Grade
4A – 72" NDT	72-inch pipeline from SPS A crossing the Florida Avenue Canal approximately 200 feet west of France Road.	Non-Destructive Testing using ultrasonic thickness gauge – Above Grade
4B – 54" NDT	54-inch pipeline from SPS D crossing the Florida Avenue Canal approximately 700 feet east of France Road.	Non-Destructive Testing using ultrasonic thickness gauge – Above Grade
5A – 72" Coupon	72-inch pipeline from SPS A where it crosses the Peoples Avenue Canal under the Almonaster Avenue Overpass.	Physical Coupon Extraction – Above Grade
5B – 60" Coupon	60-inch pipeline from SPS D where it crosses the Peoples Avenue Canal under the Almonaster Avenue Overpass.	Physical Coupon Extraction – Above Grade
6A – 60" NDT	The upstream end of the 60-inch pipeline from SPS D just after crossing Peoples Avenue.	Non-Destructive Testing using ultrasonic thickness gauge – Below Grade
7A1 & 7A2 – 48" NDT	St. Bernard Avenue north of the intersection with N. Claiborne Avenue. Two 48-inch force mains at crossing of existing drainage box culvert in the median of St. Bernard Avenue.	Non-Destructive Testing using ultrasonic thickness gauge – Below Grade
8A – 72" NDT	72-inch pipeline from SPS A at Frenchmen St. between N. Miro Street and N. Galvez Street.	Non-Destructive Testing using ultrasonic thickness gauge – Below Grade

¹ Non-destructive test = NDT. Guided wave test = GW.

The ultrasonic measurements were performed at the top of the pipe, observed external pits, weld zone areas and sites to be fitted with weld flanges for coupon removal. Ultrasonic measurements were taken with a hand-held ultrasonic meter (calibrated Krautkramer-Branson DMS UT).

5.2.4 Non-Destructive Guided Wave

Guided wave technology (GWT) is a long range ultrasonic non-destructive test developed for detecting metal loss in pipes. It is a pulse echo system designed to test large volumes of material from a single test point. GWT is primarily a screening tool to survey lengths of pipe rapidly with 100 percent coverage of the pipe wall to identify areas of metal loss. Those areas could then be further evaluated using other techniques such as radiography or conventional ultrasonic inspection if access is possible.

The GWT was used to evaluate the pipe under the Industrial Canal. Indications of flaws were identified on “A-scan plots” based on signal amplitude. Typically a focused response is used in conjunction with the signal amplitude, but a focused response was not possible for the Industrial Canal crossing due to insufficient signal response during the testing.

The classification of a response with respect to amplitude is given as a Category 1, 2 or 3 with Category 3 indicating the highest loss of pipe wall thickness. A Category 2 or 3 classification of an anomaly denotes that the amplitude of the response was such that greater than 9 percent loss of cross-sectional area is likely. A Category 1 classification denotes that a definite signal was observed and the pipe wall loss for this classification is generally between 3 and 9 percent loss of cross-sectional area.

5.3 Testing Results

Subsection 5.3.1 presents the physical inspection results. Subsection 5.3.2 presents the corrosion protection system test results. Subsection 5.3.3 presents the coupon extraction and ultrasonic testing thickness results. Subsection 5.3.4 presents the guided wave thickness results.

5.3.1 Physical Inspection and Testing Results

As noted in Section 4.2, Surface Investigation Findings, the visual ground surface inspection found several maintenance issues with the mortar coatings on the above ground pipes. The mortar coatings were damaged and deteriorated at the 60-inch pipe crossing at the Peoples Avenue Canal.

In addition to the visual inspection, the pipeline coating material from both above ground and below ground piping was also tested. The Corrpro analysis of the coal tar enamel coating system is included in **Appendix D Lining/Coating Test Results**. The coal tar enamel coating used on the exterior and the interior of the steel pipe is a bitumastic based material with good pipe adhesion properties and resilience within the mixture. This is a hot applied coating that sets on cooling. The exterior coating was wrapped with an asbestos cloth that was impregnated with the same material. The wrapping acts as a protective barrier for the relatively soft coal tar enamel.

Findings of the coating and lining evaluations show that in most areas the coating systems are breaking down. The coating systems are near or at the end of their useful life. The following is an excerpt from the Corrpro coatings evaluation report in Appendix D.

“Visual inspection show that the coating condition is extremely poor. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection no pitting located and very minor surface corrosion present.”

In addition to the visual inspection and testing of the surface coatings, the excavated soil material from each excavation was also tested. Soils test results are contained in **Appendix C Soils Test Results**. Results indicate that the soils range from “moderately corrosive” to “extremely corrosive” as defined by American Concrete Pressure Pipe Association (ACPPA). A summary of the test data by site is presented in **Table 5.2** on the following page. These ratings are based upon the low resistivity values observed.

5.3.2 Cathodic Protection System Test Results

As described in Section 2, Historical Information, both SFMs were designed with appropriate corrosion control measures. Sacrificial anode and impressed current systems were originally installed for each pipeline, although portions of the impressed current system were damaged during Hurricanes Katrina and Rita.

The impressed current cathodic protection system includes seven rectifier systems as listed in **Table 5.3**. As noted, only two of these systems are currently functional.

Table 5.3
Impressed Current Cathodic Protection System Operational Status

Rectifier Number	Address	Status
Rectifier R7	Station A 1321 Orleans Avenue	System Functional
Rectifier R8	Elysian Fields and North Roman	Destroyed by Katrina
Rectifier R9	Duels Street and Florida Boulevard	System Functional
Rectifier R10	Station D 2800 Florida Boulevard	Destroyed by Katrina
Rectifier R11	Drainage Station 5 4841 Florida Boulevard	Destroyed by Katrina; New rectifier installed, but no AC power
Rectifier R12	Benton and Florida Boulevard	Destroyed by Katrina
Rectifier R13	East Bank Wastewater Treatment Plant	Destroyed by Katrina

The two functional rectifiers were interrupted to obtain “instant off” cathodic protection potentials in accordance with NACE SP-0169. Only test Sites 7A and 8A had any appreciable potential shift from the rectifier interruption cycle (33 to 40 milivolt). Nevertheless, none of the test sites for this project “indicated minimal criteria according to NACE (-0.850 V instant-off or 100 mV shift) when measured with a CuCuSO₄ reference electrode.” Based on the potential test, all of the cathodic potentials were indicative of the “absence of effective cathodic protection.” No foreign sources of stray currents were identified along the SFM route.

5.3.3 Destructive Coupon Testing Results

Photographs of each coupon site are contained in **Appendix E Coupon Extraction Photographs**. The data output summaries for each of the coupon tests are included in **Appendix F Coupon Test Results**.

Section 5 – SFM Field Data Analysis

**Table 5.2
Soils Testing Results**

Site	Moisture (%)	pH	Chloride (ppm)	Sulfide (ppm)	Conductivity (μ mhos)	Calculated Resistivity (ohm-cm)	Sample Type	Sample Color	ACPPA Corrosivity
1A	18.00	7.6	6	0	390	2,600	Clay-loam	Gray	Very corrosive
1B	14.00	8.1	6	0	310	3,200	Clay-loam	Gray	Very corrosive
1C	26.00	7.9	240	0	1,700	590	Clay	Gray and brown	Extremely corrosive
1D	53.00	7.6	20	0	1,400	710	Clay	Gray and brown	Extremely corrosive
2A	18.00	8.4	10	0	490	2,000	Clay	Gray and brown	Very corrosive
2B	17.00	7.9	10	0	460	2,200	Clay-loam	Gray and brown	Very corrosive
3A	35.00	8.0	8	0	880	1,100	Clay	Gray-brown	Very corrosive
4A	53.00	7.7	12	0	1,000	1,000	Clay	Gray-brown	Very corrosive
4B	34.00	8.0	12	0	950	1,100	Clay	Gray-brown	Very corrosive
5A	6.80	7.7	9	0	620	1,600	Sandy loam and rocks	Gray-brown	Very corrosive
5B	30.00	7.5	2	0	500	2,000	Clay loam	Gray-brown	Very corrosive
6A	39.00	7.4	36	0	930	1,100	Clay	Gray	Very corrosive
7A	5.00	8.2	1	0	200	5,000	Sand	Gray and brown	Corrosive
8A	6.90	7.7	4	0	130	7,700	Sand	Light brown	Moderately corrosive

The laboratory tested the coupons for material composition including: percentages of carbon, sulfur, manganese, phosphorus, silicon, copper, nickel, chromium and molybdenum. Mechanical properties included determination of the yield point, tensile strength and elongation percentage. These chemical/mechanical properties were compared against American Standard Testing Methods (ASTM) design standards applicable to various pipe materials. This pipe material conforms to ASTM A283 plate material.

Each coupon was measured for thickness using micrometers. The resulting measured thickness data is presented in **Table 5.4** on the following page. The measured thickness compared to the wall thickness ranges from a 4.1 percent “loss” to a 2.4 percent “gain”. The overall average of all the samples is only 0.7 percent less than the original design thickness.

The thickness measurements shown in tests 1 through 10 are plate thickness measured on a pre-determined grid whereas the pit measurements P1 through P7 are localized measurements at specific corrosion points. The minimum thickness noted above was the value carried into the numerical analysis for the pipe coupon assessment presented in Section 6, Structural Evaluation Conclusions.

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Table 5.4
Coupon Thickness Data Summary^{1, 2}

Site 1C – 66” Coupon		Site 1D – 54” Coupon		Site 3A – 54” Coupon		Site 5A – 72” Coupon		Site 5B – 60” Coupon	
Design Thickness 0.375		Design Thickness 0.500		Design Thickness 0.500		Design Thickness 0.438		Design Thickness 0.375	
Test	Thickness								
1	0.367	1	0.495	1	0.500	1	0.419	1	0.385
2	0.366	2	0.499	2	0.520	2	0.422	2	0.386
3	0.364	3	0.497	3	0.530	3	0.422	3	0.384
4	0.365	4	0.499	4	0.499	4	0.419	4	0.383
5	0.364	5	0.495	5	0.500	5	0.420	5	0.384
6	0.363	6	0.494	6	0.520	6	0.423	6	0.381
7	0.365	7	0.497	7	0.500	7	0.419	7	0.384
8	0.365	8	0.491	8	0.510	8	0.417	8	0.385
9	0.364	9	0.497	9	0.500	9	0.418	9	0.382
10	0.366	10	0.498	10	0.498	10	0.422	10	0.384
Min.	0.363	Min.	0.491	Min.	0.498	Min.	0.417	Min.	0.381
Ave.	0.365	Ave.	0.496	Ave.	0.508	Ave.	0.420	Ave.	0.384
Max.	0.367	Max.	0.499	Max.	0.530	Max.	0.423	Max.	0.386
Thickness Remaining at Pits		Thickness Remaining at Pits		Thickness Remaining at Pits		Thickness Remaining at Pits		Thickness Remaining at Pits	
P1	0.349		0.470		0.430		N/A		N/A
P2	0.308		N/A		0.424		N/A		N/A
P3	0.397		N/A		0.422		N/A		N/A
P4	N/A		N/A		0.436		N/A		N/A
P5	N/A		N/A		0.421		N/A		N/A
P6	N/A		N/A		0.460		N/A		N/A
P7	N/A		N/A		0.431		N/A		N/A
Measured Min.		Measured Min.		Measured Min.		Measured Min.		Measured Min.	
0.308		0.470		0.421		0.417		0.381	

¹ Not applicable = N/A.

² Initial thickness measurements performed prior to plate preparation to remove weld splatters, remaining surface coatings and rust deposits.

Section 5 – SFM Field Data Analysis

5.3.4 Non-Destructive Ultrasonic Results

The data output summaries for each of the ultrasonic sites are included in **Appendix G Ultrasonic Test Results**. Ultrasonic pipe wall thickness measurements were taken at thirteen sites: 1A, 1B, 1C, 1D, 3A, 4A, 4B, 5A, 5B, 6A, 7A1, 7A2 and 8A once the raw steel was exposed. **Table 5.5** summarizes the ultrasonic test measurements. As can be seen, in some cases the thickness is greater than the design wall thickness. As with the measured coupon thicknesses discussed above, the average ultrasonic thickness measurements compared to the design wall thickness ranges from a 6.1 percent “loss” to a 3.2 percent “gain”. The overall average of the samples is only 1.0 percent less than the original design wall thickness.

Table 5.5
Ultrasonic Thickness Data Summary

Test Site ¹	Design Wall Thickness	Actual Ultrasonic Measured Wall Thickness		Percentile Data				
				25%	50%	75%	90%	100%
1A – 66” NDT	0.375	Minimum	0.357	0.369	0.372	0.378	0.382	0.399
		Average	0.373					
		Maximum	0.399					
1B – 54” NDT	0.375	Minimum	0.342	0.366	0.370	0.375	0.379	0.386
		Average	0.371					
		Maximum	0.386					
1C – 66” NDT	0.375	Minimum	0.286	0.337	0.357	0.375	0.375	0.399
		Average	0.352					
		Maximum	0.399					
1D – 54” NDT	0.500	Minimum	0.476	0.510	0.516	0.521	0.526	0.540
		Average	0.516					
		Maximum	0.540					
3A – 54” Coupon	0.500	Minimum	0.482	0.506	0.511	0.516	0.520	0.539
		Average	0.511					
		Maximum	0.539					
4A – 72” NDT	0.438	Minimum	0.409	0.423	0.426	0.429	0.435	0.446
		Average	0.427					
		Maximum	0.446					
4B – 54” NDT	0.375	Minimum	0.332	0.371	0.378	0.386	0.391	0.399
		Average	0.378					
		Maximum	0.399					
5A – 72” Coupon	0.438	Minimum	0.412	0.424	0.427	0.429	0.436	0.449
		Average	0.428					
		Maximum	0.449					

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Table 5.5 Continued on next page.

**Table 5.5 Continued
Ultrasonic Data Summary**

Test Site	Design Wall Thickness	Actual Ultrasonic Measured Wall Thickness	Percentile Data				
5B Side – 60” Coupon	0.375	Minimum 0.327	25%	50%	75%	90%	100%
		Average 0.377	0.370	0.377	0.384	0.389	0.399
		Maximum 0.399					
5B Top – 60” Coupon	0.375	Minimum 0.350	25%	50%	75%	90%	100%
		Average 0.373	0.367	0.373	0.379	0.384	0.394
		Maximum 0.394					
6A – 60” NDT	0.375	Minimum 0.284	25%	50%	75%	90%	100%
		Average 0.365	0.358	0.365	0.371	0.377	0.396
		Maximum 0.396					
7A1 – 48” NDT	0.500	Minimum 0.467	25%	50%	75%	90%	100%
		Average 0.492	0.487	0.492	0.496	0.501	0.519
		Maximum 0.519					
7A2 – 48” NDT	0.500	Minimum 0.449	25%	50%	75%	90%	100%
		Average 0.491	0.485	0.491	0.497	0.500	0.531
		Maximum 0.531					
8A – 72” NDT	0.375	Minimum 0.352	25%	50%	75%	90%	100%
		Average 0.369	0.365	0.369	0.372	0.375	0.393
		Maximum 0.393					

¹ Non destructive test = NDT.

The minimum, average and maximum values shown in the table are the statistical results of the numerous ultrasonic measurements. The “Minimum” thickness shown in Table 5.4 is the value used in Section 6, Structural Evaluation Conclusions.

The “Percentile Data” data defines the numerical percentage value (25%, 50%, 75%, 90% and 100%) of which the measured wall thickness values are smaller. The 50% value is approximately the same as the “average” value and the 100% value is the same as the “maximum” value.

As can be seen from Table 5.5, in some cases the thickness is greater than the design wall thickness. Wall thickness can vary from design wall thickness due to variations in the manufacturing process. Typically these variations are expressed as a mill tolerance.

As part of the data evaluation process, ultrasonic measurements were also taken after plate preparation to remove weld splatters, remaining coating materials and rust deposits to calibrate the final coupon thicknesses versus ultrasonic thickness measurements. The calibration results are shown in **Table 5.6**. As can be seen, the range in measurements for the ultrasonic device was from -1.03 percent to +1.86 percent, resulting in a roughly 2 percent error band.

**Table 5.6
Plate Thickness and Ultrasonic Measurement Calibration Summary**

Site	Ultrasonic Reading (inches)	Caliper Reading (inches)	Delta Ultrasonic to Caliper (inches)	Percent Error
1C-1	0.369	0.370	-0.001	-0.27%
1C-2	0.310	0.311	-0.001	-0.32%
1C-3	0.326	0.328	-0.002	-0.61%
1D-1	0.507	0.501	0.006	1.20%
1D-2	0.505	0.501	0.004	0.80%
1D-3	0.508	0.505	0.003	0.59%
3A-1	0.492	0.490	0.002	0.41%
3A-2	0.484	0.487	-0.003	-0.62%
3A-3	0.498	0.498	0.000	0.00%
5A-1	0.439	0.431	0.008	1.86%
5A-2	0.435	0.432	0.003	0.69%
5A-3	0.422	0.426	-0.004	-0.94%
5B-1	0.392	0.389	0.003	0.77%
5B-2	0.385	0.389	-0.004	-1.03%
5B-3	0.385	0.384	0.001	0.26%

It is important to recognize that the information presented from this data set is only a very small sampling of the complete pipe system for each of the SFMs. Wall thicknesses in other areas of the SFMs are expected to vary from this limited data set.

5.3.5 Non-Destructive Guided Wave Results

Guided wave tests were completed on the 66-inch and the 54-inch pipes crossing the Industrial Canal. The work included traditional axisymmetric scans of the pipes at multiple frequencies using both longitudinal and torsional mode excitation. Phased array focusing was not used in these scans as bends were encountered on both pipes in both directions within close proximity to the placement of the tool resulting in an insufficient signal. Focusing currently cannot be used to enhance inspection results beyond such bends.

The 66-inch pipe had a reasonable signal to noise ratio was obtained in the “backwards” direction heading west towards the Industrial Canal. Several weld-like indications were noted and two Category 1 indications were noted. As previously defined, Category 1 is the lowest category and the pipe wall loss for this classification is generally between 3 and 9 percent of the cross-sectional area. The signal was reduced in the forwards direction as the tool was placed

directly behind a steel band. Therefore, the confidence in this inspection is decreased. Several weld-like indications were noted.

The 54-inch pipe did not have as good a signal to noise ratio. Only half of the available transducer modules were used due to complications with the electronics driving hardware, which most likely caused a loss of penetration power. Several weld-like indications and two Category 1 indications were noted in the backwards direction heading west towards the Industrial Canal. The quality of the scan in the forwards direction again was not as good as the tool was placed directly against the coal tar coating. A weld-like indication was noted in the forwards direction.

The data output summaries for each of the guided wave are included in **Appendix H Guided Wave Test Results**.

As with the pipe wall thickness data from the coupons and the ultrasonic testing, it is important to recognize that the information presented from this data set is only a very small sampling of the complete pipe system for each of the SFMs and results in other sections of the SFMs is expected to vary from this limited data set.

Section 6

Structural Evaluation Conclusions

6.1 General

Methodologies for evaluation of remaining pipe wall thickness and associated pipeline life are limited. Several methods used in this evaluation are listed below:

- Hoop stress calculations
- Buckling calculations
- Deflection calculations

To estimate remaining service life time, it is required to extrapolate the loss of wall thickness due to corrosion into the future. Studies of external surface corrosion in steel pipelines have used power law time dependencies for corrosion pit depth to reflect the fact that corrosion product build up slows the corrosion rate over time. However, in this study there is only one measurement of pipe wall thickness so a non-linear equation can not be confidently fitted to the data. Furthermore, the force main may also be suffering internal corrosion which would follow a different time dependency to external corrosion. With that in mind, it is a reasonable approximation to assume that the corrosion rate is linear and remains constant over the remaining service life of the main. The remaining service life could then be based on the calculated times for the following conditions.

1. The point when full corrosion pitting through the pipe wall occurs, resulting in pipe leakage.
2. The point when pipe wall thickness decreases sufficiently such that yielding (deflection) of the pipe wall occurs under applied loading.
3. The point when the pipe wall thickness decreases sufficiently such that buckling occurs under applied pressures.

The remaining service life would then be taken as the shortest time from these three calculations. Based on the three calculation methods above and a linear corrosion rate; calculations can be performed to estimate the potential remaining service life of the pipe. The calculations for the SFMs evaluated herein are based on a limited number of data points. Other non-sampled locations could have a different corrosion rate and thus have a different life expectancy.

The first task in the evaluation calculation process is to define the conditions acting on the pipeline. **Table 6.1** lists the observed or calculated parameters used in the pipe life calculations.

As can be seen from **Table 6.1**, the parameters include the pipe diameter, design wall thickness (physical, ultrasonic and guided wave measurements), lining and coating information, modulus of soil reaction E' , which is an indicator of the soil's side support value), pipe cover, traffic loading, depth of ground water and peak pressure in the pipeline. Each of these parameters is used in at least one of the calculation methods.

Section 6 – Structural Evaluation Conclusions

Table 6.1
Input Data Summary for Structural Evaluations ¹

Sample Number	Pipe Data						Ultrasonic						Operational Conditions on Pipe				
	Design Wall Thickness (inches)	Yield Stress of Steel (psi)	Wall Thickness From Coupon	Min. Wall Thickness From Coupon	Lining Type	Coated Type	Percentile of Thickness Measurements					Wall Thickness for Evaluation	Modulus of Soil Reaction E' (psi)	Pipe Cover (feet)	Traffic Load (psf)	Ground Water Depth Over Pipe (feet)	Peak Pressure (psi)
							25%	50%	75%	90%	100%						
1A	0.375	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.369	0.372	0.378	0/382	0.399	0.357	Above grade	N/A	N/A	N/A	17.9
1B	0.375	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.366	0.370	0.375	0.379	0.386	0.342	Above grade	N/A	N/A	N/A	13.4
1C	0.375	45,000	0.371	0.305	Coal tar	Coal tar/mortar	0.337	0.357	0.370	0.375	0.399	0.286	200	9.5	0	8.5	3.4
1D	0.500	37,000	0.497	0.467	Coal tar	Coal tar/mortar	0.510	0.516	0.521	0.526	0.540	0.470	200	N/A	N/A	N/A	3.3
2A	0.375	40,000	N/A	N/A	Coal tar	Coal tar/mortar	N/A	N/A	N/A	N/A	N/A	0.341	Above grade	N/A	N/A	N/A	0.0
2B	0.500	40,000	N/A	N/A	Coal tar	Coal tar/mortar	N/A	N/A	N/A	N/A	N/A	0.455	Above grade	N/A	N/A	N/A	28.8
3A	0.500	40,000	0.504	0.429	Coal tar	Coal tar/mortar	0.506	0.511	0.516	0.520	0.539	0.421	Above grade	N/A	N/A	N/A	21.1
4A	0.438	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.423	0.426	0.429	0.435	0.446	0.409	Above grade	N/A	N/A	N/A	36.6
4B	0.500	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.371	0.378	0.386	0.391	0.399	0.332	Above grade	N/A	N/A	N/A	33.1
5A	0.438	37,000	0.421	0.421	Coal tar	Coal tar/mortar	0.424	0.427	0.429	0.436	0.449	0.412	Above grade	N/A	N/A	N/A	40.5
5B	0.375	48,000	0.385	0.381	Coal tar	Coal tar/mortar	NA	NA	NA	NA	NA	0.327	Above grade	N/A	N/A	N/A	45.9
6A	0.375	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.358	0.365	0.371	0.377	0.396	0.284	200	10.4	0	9.4	43.0
7A1	0.500	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.487	0.492	0.496	0.501	0.519	0.467	200	1.0	1,800	0.5	57.9
7A2	0.500	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.485	0.491	0.497	0.500	0.531	0.467	200	1.0	1,800	0.5	57.9
8A	0.375	40,000	N/A	N/A	Coal tar	Coal tar/mortar	0.365	0.369	0.372	0.375	0.393	0.352	200	6.2	200	5.2	49.5

¹ Not applicable = N/A. Not available = NA. No data = ND. Beyond the model = BM.

6.2 Evaluation Methodologies

As noted, three methodologies were used to calculate the potential remaining pipe life for the SFMs. Each of these methods, hoop stress, deflection and buckling, will be discussed in detail in the following subsections.

6.2.1 Hoop Stress Evaluation

Information required to perform the hoop stress evaluations includes:

- Hydraulic information such as elevation of the hydraulic grade line and associated pressure
- Pipe strength as indicated by the yield strength for the pipe parent material
- Industry standard for evaluation from such organizations as the American Society of Materials Engineering (ASME) and the American Water Works Association (AWWA)

One of the first items performed for the evaluation was completion of a hydraulics model of the SFMs. This model looked at the various operational scenarios for the system and associated flow rates. The hydraulic grade lines from the various flow conditions were translated into operating pressures within the pipe. Peak pressures from this modeling were used in the pipe condition evaluation using the Hoop Stress equations.

Hoop stress is simply the stress in the pipe wall created by internal pressure. The equation used for this calculation is as follows:

$$t = \frac{p d}{2 s}$$

Where:

t = pipe wall thickness in inches

p = internal pressure in psi

d = outside diameter of pipe(not including coatings)

s = allowable stress in the steel pipe wall (see AWWA M-11 Manual for Steel Pipe Design for appropriate factors of safety)

Using this equation and the information from **Table 6.1**, spreadsheets were developed to estimate the remaining service life of the pipelines assuming various factors of safety were applied. **Table 6.2** summarizes the Hoop Stress calculations for the different test sites.

As shown in **Table 6.2**, the calculated remaining service life varies from under 100 years (83 years) to over 600 (646 years). These numbers are to be used only as condition indicators since other factors that are not included in the evaluation can significantly reduce the remaining pipe life. In general the larger numbers would indicate that hoop stress is not a likely failure mode for the SFM piping and that other corrosion and or loading conditions may actually govern the life of the pipes. Some of these other conditions could include pitting (localized corrosion, which penetrates the pipe wall thickness), deflection under loads or buckling. Two of these other conditions, deflection and buckling, are evaluated in more detail in the remainder of this section. However, pitting, extended through the pipe wall, is not considered since it is a localized phenomenon and not a general failure mode.

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**Table 6.2
Hoop Stress Evaluation Summary ¹**

Sample Number	Pipe Size (inches)	Design Wall Thickness (inches)	Actual Minimum Wall Thickness (inches)	Allowable Yield Stress (psi)	Corrosion Rate (mils/year)	Remaining Life to Factor of Safety = 1 ² (years)	Comments
1A	66	0.375	0.357	40,000	0.5294	646	More than adequate hoop capacity remains
1B	54	0.375	0.342	40,000	0.9706	343	More than adequate hoop capacity remains
1C	66	0.375	0.286	45,000	2.6176	108	More than adequate hoop capacity remains
1D	54	0.500	0.470	37,000	0.8824	530	More than adequate hoop capacity remains
2A	66	0.375	0.341	40,000	0.9926	331	More than adequate hoop capacity remains
2B	54	0.500	0.455	40,000	1.000	436	More than adequate hoop capacity remains
3A	54	0.500	0.421	40,000	1.7556	232	More than adequate hoop capacity remains
4A	72	0.438	0.409	40,000	0.8529	441	More than adequate hoop capacity remains
4B	54	0.500	0.332	40,000	3.7333	83	More than adequate hoop capacity remains
5A	72	0.438	0.421	37,000	0.7647	487	More than adequate hoop capacity remains
5B	60	0.375	0.327	48,000	- 0.2941 ³	298	More than adequate hoop capacity remains
6A	60	0.375	0.284	40,000	0.5000	137	More than adequate hoop capacity remains
7A1 & 7A2	48	0.500	0.467	40,000	0.4412	445	More than adequate hoop capacity remains
8A	72	0.375	0.352	40,000	0.2941	454	More than adequate hoop capacity remains

¹ Not applicable = N/A. Not available = NA. No data = ND. Beyond the model = BM.

² Pipeline lives beyond 100 years are somewhat meaningless since other forms of failure are likely to shorten pipe life.

³ Measured pipe wall thickness was greater than the design pipe wall thickness giving a meaningless negative corrosion rate.

6.2.2 Pipe Loading and Deflection

Pipe deflection is not normally used as a pipe condition assessment tool; however, due to the low pipe pressures, high traffic loads and shallow soils cover, these conditions could affect the life of the SFMs.

In order to use deflection as a condition assessment criteria a method needs to be defined to determine the point in time for a given wall thickness when an over deflected condition would exist. For this evaluation several check points were selected as listed in **Table 6.3**.

Table 6.3
Deflection Check Points

Specified Deflection	Comment
Time until deflection = 2%	Cracking of cement mortar lining/coating likely
Time until deflection = 3%	Cracking of internal cement mortar lining likely
Time until deflection = 5%	Cracking of flexible lining and coating likely
Time until deflection = 20%	Pipe inversion through over deflection likely

Each of these deflection states were checked in the calculations to determine the associated time to reach this deflection condition. The same linear loss rate per year (mils/yr) was used for this part of the pipe condition assessment. Time sequencing was accomplished by looking at each future year's projected remaining wall thickness and performing deflection calculations based on the applied loading conditions. If the deflection was exceeded for that year, a flag was set that defined the future life of the pipe at that deflection condition.

The equations used in the evaluation are taken from the AWWA M-11 Manual for Steel Pipe Design. This manual provides the industry standard for steel pipeline design, including the equations and methodology to be followed. The equation for deflection from that standard is shown below.

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$$\Delta x = D_l \left(\frac{K W r^3}{EI + 0.061 E' r^3} \right)$$

Where:

Δx = horizontal deflection of pipe (inches)

D_l = deflection lag factor (1.0 to 1.5)

K = bedding constant (0.1)

W = load per unit of pipe length (pounds per linear inch of pipe)

r = radius (inches)

EI = pipe wall stiffness (inch-pound)

Where: E = modulus of elasticity (30,000,000 psi for steel and 4,000,000 psi for cement mortar)

I = transverse moment of inertia per unit length of pipe wall

E' = modulus of soil reaction (pounds per square inch [psi])

Source: AWWA MANUAL M11 - Steel Pipe - A Guide for Design and Installation

This equation requires the pipe dimensions, depth of bury, traffic loading, E' (soil's side support value) and the pipe stiffness to be able to calculate the pipe reaction to the loading; i.e., vertical deflection of the pipe. The deflection criteria shown above, defines specific check points for the various lining and coating system types that are used on steel pipelines. The SFMs for this evaluation are coal tar enamel lined and coated. This system was a flexible system when first applied to the pipeline; however, it has become brittle with age and will disband from the pipe as deflection increases. Deflections above 5 percent could cause cracking in the lining and coating system that would jeopardize the integrity of the pipe and allow corrosion to continue to attack the steel.

A summary of those calculations is presented in **Table 6.4**. As can be seen, the deflections are generally exceeding the 5 percent limit, but are not to the 20 percent range, where inversion of the pipe could be possible. Inversion of the "pipe can" is one definition of failure for a flexible steel pipeline, as the deflection nears the higher deflection ranges the factor of safety for pipe support decreases. At deflections greater than 5 percent, gasketed pipe joints (not applicable in this case since the SFM joints are welded joints) can begin leaking, and the lining and coating, as noted above, can disband from the pipe.

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**Table 6.4
Deflection Evaluation Summary ¹**

Sample Number	Pipe Size (inches)	Remaining Life to Deflections Of				Comments
		2%	3%	5%	20%	
1A	66	N/A	N/A	N/A	N/A	Elevated pipe
1B	54	N/A	N/A	N/A	N/A	Elevated pipe
1C	66	1	1	1	295	Greater than 5% at 1 year; greater than 20% at 295 years
1D	54	N/A	N/A	N/A	N/A	In Valve Box
2A	66	1	1	1	457	Greater than 5% at 1 year; greater than 20% at 457 years
2B	54	1	1	1	BM	Deflection greater than 5%; 20% deflection is beyond the model
3A	54	N/A	N/A	N/A	N/A	Elevated pipe
4A	72	N/A	N/A	N/A	N/A	Elevated pipe
4B	54	N/A	N/A	N/A	N/A	Elevated pipe
5A	72	N/A	N/A	N/A	N/A	Elevated pipe
5B	60	N/A	N/A	N/A	N/A	Elevated pipe
6A	60	1	1	1	379	Greater than 5% at 1 year; greater than 20% at 379 years
7A1 & 7A2	48	1	1	1	205	Greater than 5% at 1 year; greater than 20% at 205 years
8A	72	1	1	367	BM	Deflection greater than 5%; 20% deflection is beyond the model

¹ Not applicable = N/A. Not available = NA. No data = ND. Beyond the model = BM.

6.2.3 Pipe Buckling

Buckling of a flexible steel pipe, such as the SFMs, could occur if the pipe wall stiffness were to be exceeded by applied internal and external pressures. Internal pressures usually push out on the pipe wall; however, under surge events, a vacuum can be created in the pipeline, which could possibly exceed the capability of the pipe to resist this pressure loading, causing the pipeline to buckle. A buckled pipe has the “pipe can” inverted into the center of the pipeline. This condition reduces the flow capacity significantly and can even cause failure of the pipe wall due to the sharp bends created in the pipe wall by the inversion process.

A down surge condition is created when the flow of a liquid ceases abruptly, such as at a check valve following an emergency pump shut down. This dramatic reduction in flow in long, flat force mains can lead to a complete vacuum (-14.7 psi) within the pipe. Since some of the air valves are manually operated on the SFMs, and would normally be closed (not automatic), this analysis assumes the full vacuum condition. This is a conservative assumption due to the low number of air/vacuum valves that would allow air to enter into the pipelines.

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The buckling calculations are a two step process, the first step is to calculate the allowable buckling pressure based on the pipe stiffness, and the second is to define the applied buckling loads that are being applied to the pipeline by soil loads, groundwater, traffic loadings and vacuum pressure.

The applied loading does not change; however, the allowable loading decreases as the pipe wall thickness decreases (pipe corrodes). The calculations check the allowable buckling pressure for each future year using the linear pipe wall corrosion loss (mils/year) that results from the corrosion to date. This is then converted to a Buckling Factor of Safety (FS), defined as the ratio between allowable buckling pressure and the applied loading, which is checked against the four criteria shown in **Table 6.5**. If any of the criteria is exceeded, a flag is set and the estimated life noted for that exceedance.

**Table 6.5
Buckling Check Points**

Buckling Factor of Safety (FS)	Comment
Time until FS = 1.75	Low buckling potential
Time until FS = 1.5	Moderate buckling potential
Time until FS = 1.25	High buckling potential
Time until FS = 1.0	Very high buckling potential

The allowable buckling pressure is defined by AWWA M-11 as follows:

$$q_a = \left(\frac{1}{FS} \right) \sqrt{32 R_w B' E' \frac{EI}{D^3}}$$

Where:

q_a = allowable buckling pressure (psi)

FS = design factor of safety = 2.0

R_w = water buoyancy factor

$$= 1 - 0.33 \left(\frac{h_w}{h} \right), \quad 0 \leq h_w \leq h$$

where h_w = height of water surface above top of pipe (inch)

B' = empirical coefficient of elastic support (dimensionless)

$$= \frac{1}{1 + 4 e^{(-0.065 H)}}$$

where: H = height of fill above pipe (feet) (Reference ANSI/AWWA C950-81, Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe, Appendix A)

Source: AWWA MANUAL M11 - Steel Pipe - A Guide for Design and Installation

The recommended factor of safety has been revised by the M-11 committee in the new 4th Edition to the manual as $FS = 2.0$.

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The applied buckling pressure is made up of several load conditions and is covered by two equations in the M-11 manual, as shown below.

The first equation considers the pressures from the earth loads and from in internal vacuum load.

$$\gamma_w h_w + R_w \frac{W_c}{D} + P_v \leq q_a$$

Where:

- h_w = height of water above conduit (inches)
- γ_w = specific weight of water (0.0361 pounds per cubic inch)
- P_v = internal vacuum pressure (psi)
- W_c = vertical soil load on pipe per unit length (pounds per linear inch of pipe)

Source: AWWA MANUAL M11 - Steel Pipe - A Guide for Design and Installation

The second equation is similar with a traffic load component; it is not required to apply vacuum and traffic simultaneously.

$$\gamma_w h_w + R_w \frac{W_c}{D} + \frac{W_L}{D} \leq q_a$$

Where:

- W_L = live load on conduit (pounds per linear inch of pipe)

Source: AWWA MANUAL M11 - Steel Pipe - A Guide for Design and Installation

Buckling calculations are summarized in **Table 6.6**. As can be seen, buckling is the controlling condition for the SFMs. The factor of safety used by the AWWA M-11 design standard is 2.0. In all cases the buckling life has exceeded this point within the first year and in most cases the factor of safety is 1.25 or less. This is typical of large diameter pipelines installed in flat, soft soil with high groundwater conditions.

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**Table 6.6
Buckling Evaluation Summary**

Sample Number	Pipe Size (inches)	Remaining Life (years)	Comments
1A	66	1	Very high buckling potential
1B	54	28	Very high buckling potential
1C	66	1	Very high buckling potential
1D	54	100	To FS = 1.75, Low buckling potential
2A	66	21	Very high buckling potential
2B	54	28	Very high buckling potential
3A	54	16	54 years to FS = 1.00, Very high buckling potential
4A	72	1	Very high buckling potential
4B	54	7	To FS = 1.25, High buckling potential, 16 year to Very high
5A	72	1	Very high buckling potential
5B	60	1	Very high buckling potential
6A	60	1	Very high buckling potential
7A1 & 7A2	48	121	Low buckling potential
8A	72	1	Very high buckling potential

All of the sites with a 1 year expected life are at a very high potential for buckling. As the pipeline continues to corrode, this potential will increase. If corrective action to add more air/vacuum type relief valves on the SFMs is not taken, a buckling failure of one or both of the pipelines is a high possibility based on the conservative assumptions on which this analysis is based.

6.3 Structural Evaluation Results, Conclusions and Recommendations

Both the hoop stress and pipe deflection evaluations did not appear to be the controlling factor for these pipelines. As noted above, the buckling potential of the pipeline is very high and modifications to the air valves or other devices to limit vacuum loads along the pipeline alignment are needed.

6.3.1 Evaluation Results

Table 6.7 on the following page summarizes the three structural methods used in this evaluation. Again as can be seen from this table, the buckling condition is the controlling structural condition for the SFMs.

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Table 6.7
SFM Structural Evaluation Summary ¹

Sample Number	Pipe Size (inches)	Hoop Stress Evaluation		Deflection Evaluation		Buckling Evaluation	
		Life (years)	Comments	Life (years)	Comments	Life (years)	Comments
1A	66	646	More than adequate hoop capacity remains	NA	Elevated pipe	1	Very high buckling potential
1B	54	343	More than adequate hoop capacity remains	NA	Elevated pipe	28	Very high buckling potential
1C	66	108	More than adequate hoop capacity remains	295	Deflection > 5%, > 20% at 295 years	1	Very high buckling potential
1D	54	530	More than adequate hoop capacity remains	NA	In Valve Box	100	To FS = 1.75, Low buckling potential
2A	66	331	More than adequate hoop capacity remains	457	Deflection > 5% at 1 year, > 20% at 457 years	21	Very high buckling potential
2B	54	436	More than adequate hoop capacity remains	BM	Deflection > 5%, 20% is beyond the model	28	Very high buckling potential
3A	54	232	More than adequate hoop capacity remains	NA	Elevated pipe	16	54 years to FS = 1.00, Very high buckling potential
4A	72	441	More than adequate hoop capacity remains	NA	Elevated pipe	1	Very high buckling potential
4B	54	83	More than adequate hoop capacity remains	NA	Elevated pipe	7	To FS = 1.25, High buckling potential (16 years to very high buckling potential)
5A	72	487	More than adequate hoop capacity remains	NA	Elevated pipe	1	Very high buckling potential
5B	60	298	Measured thickness > design thickness	NA	Elevated pipe	1	Very high buckling potential
6A	60	137	More than adequate hoop capacity remains	379	Deflection > 5% at 1 year; > 20% at 379 years	1	Very high buckling potential
7A1 & 7A2	48	445	More than adequate hoop capacity remains	205	Deflection > 5% at 1 year, > 20% is at 205 years	121	Low buckling potential
8A	72	454	More than adequate hoop capacity remains	BM	Deflection > 5%, 20% is BM	1	Very high buckling potential

¹ Not applicable = N/A. Not available = NA. No data = ND. Beyond the model = BM.

6.3.2 Evaluation Conclusions and Recommendations

As can be seen from **Table 6.7** above, adequate wall thickness exists for the low pressures of the force main pipelines. However, the limited nature of this evaluation with only 15 sample points taken from many miles of pipeline should be taken into consideration. When selecting the

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sample points, an attempt was made to represent the most likely locations for deteriorated conditions as well as to capture samples that would be representative of the typical condition of the pipelines.

A summary of the overall findings and recommendations is provided in **Section 8 – Findings, Conclusions and Recommendations**.

Section 7

Reliability Considerations

7.1 Potential Failure Impacts

Impacts to the environment occur when there is a leaking pipe or a pipe failure adjacent to an environmentally sensitive area. The most significant impacts are likely to occur at, or near, canals and wetland areas. Water crossings offer the most potential adverse environmental impact because a leaking force main or a pipe failure can result in larger quantities of untreated wastewater flowing directly into the water body.

Impacts to human health occur when people are unknowingly exposed to wastewater and contact inadvertently occurs. Public locations such as schools, where children might not realize that the water is wastewater rather than storm water, pose the most potential adverse human health impact. Other sensitive populations include people with immune-compromised systems. Locations where such populations may come in contact with leaking or spilled wastewater could include hospitals, nursing homes or other medical facilities and offices.

Catastrophic pipeline failure impacts also have the potential for economic disruption. Large failures could impact traffic patterns or rail transportation if the failure occurs under a significant highway or railroad line. Further, given that the SFMs carry a significant portion of the City's wastewater flow to the EBWWTP, any catastrophic force main failure for which diversion flow facilities cannot be readily implemented, could disrupt normal wastewater flow patterns and cause significant disruption.

As part of the surface inspection of the SFM routes, such potentially sensitive impact locations were noted. Additionally, the original design drawings were reviewed and sensitive canal and levee crossing locations noted.

7.2 Identified Reliability Threats and Proposed Responses

The reliability of these force mains is determined by the extent to which the three criteria (i.e. hoop stress, buckling and deflection) are satisfied. The structural evaluations of these criteria concluded the following:

1. Hoop Stress: At current rates of pipe wall loss, loading and soil conditions these pipes are not likely to fail by bursting over the next 50-years.
2. Deflection: At current rates of pipe wall loss, loading and soil conditions these pipes are not likely to fail by excess deflection over the next 50-years.
3. Buckling: When subjected to existing loads, the current pipe wall thickness and soil conditions do not provide the desired factors of safety against failure by buckling. To be clear, the results are the same if the evaluation is performed with the design pipe wall thickness. These pipes have, however, decades of service where vacuum and vehicular loads have been present and yet not suffered a noticeable failure from these causes. This record of performance is certainly influenced by factors not available for consideration in this project. Examples of these would include:

Section 7 – Reliability Considerations

- The pipe was evaluated for a full vacuum loading condition. A full vacuum can develop in response to power failures or sudden shut down of the pumping systems. Whether a full vacuum develops or not would require a non-steady state evaluation of pressure transients. The Board’s existing hydraulic model is a steady state evaluation tool that is not designed to predict the pressure transients that occur in the seconds after these events occur. Factors such as the actual performance (e.g. both operability and capacity) of existing automatic valves and the stored energy properties of the pumps would all affect pressure drops experienced during these events. Thus the actual loading on the pipe may differ from those used in this analysis of a full vacuum.

- The weight of vehicles where the pipes cross under roads may not be imparting the loads used in this analysis. This could result from local usage patterns where H20 wheel loads are infrequent or from load distribution due to pavement design or improved soil properties.

- The actual strength of the pipe wall was conservatively estimated. The remaining thickness at the deepest recorded pit was used as the assumed thickness for the entire wall section. The buckling performance then does not consider the remaining wall thickness that is actually present. Although analytical tools exist to evaluate strength based on the exact geometry of pipe pits, that approach is inappropriate with this level of sampling. Thus, the wall thickness assumption is conservative and reasonable given the conditions of this project.

Data was gathered and assumptions were established to provide inputs to each parameter required to evaluate each criteria. Some of these parameters are infeasible to ‘improve’ at this stage in the life-cycle of these pipes. Examples would include: pipe diameter, groundwater depth, depth of cover, soil corrosivity, and performance of the interior or exterior coating systems. Other parameters can still be managed to retain the current performance for hoop stress and deflection and to improve performance for buckling. Examples of these are shown in the following table:

**Table 7.1
Controllable Parameters That Affect Reliability**

Criteria	Parameter
Hoop Stress	<ul style="list-style-type: none"> • Manage loads by controlling operating pressures to current ranges • Maintain remaining (current) pipe wall thickness
Buckling	<ul style="list-style-type: none"> • Vacuum Loads <ul style="list-style-type: none"> ○ Analyze ability of existing systems to prevent vacuum loads or install additional systems to prevent vacuum loads ○ Maintain remaining (current) pipe wall thickness • Vehicular Loads <ul style="list-style-type: none"> ○ Analyze site specific conditions to better define these loads on the pipe or reduce loadings by limiting usage ○ Improve the ability of the pipe-soil system to resist applied loads ○ Maintain remaining (current) pipe wall thickness
Deflection	<ul style="list-style-type: none"> • Maintain remaining (current) pipe wall thickness

Retaining or improving reliability results from managing the controllable parameters that generate the loads on the pipes or the ability of the pipes to resist those loads. The Board can pursue the following actions to improve reliability of these pipelines against buckling and retain their reliability for hoop stress and deflection.

7.2.1 Managing Applied Loads

The controllable loads applied to these pipelines result from operating pressure, external pressure resulting from vacuum loads, and vehicular loads at road crossings. Pressure loads from normal operations are well within the existing capacity of these pipelines. Caution should be exercised to prevent operating conditions that could even temporarily cause significant increases in pressure.

Improving the reliability against buckling failure will require an evaluation of the existing system for hydraulic transients resulting from sudden loss of flow from pump stations connected to these force mains. A non-steady state model will need to be developed to either confirm the adequacy of existing systems or to identify additional protective measures to limit vacuum loads. Buckling can also result from vehicular loads. A site specific evaluation of loading and structural conditions at road crossings is required to better define the potential for this mode of failure. The Board has never observed either of these failure modes. However, these systems are not static in either their loading or ability to resist loads. Thus, future performance for buckling must be better defined to manage overall reliability.

7.2.2 Managing Resistance to Loads

The controllable parameters that affect the ability of these pipes to resist loads are the wall thickness and support provided by the surrounding soil. Maintaining wall thickness is a component of retaining or improving reliability for each of the three criteria. There are no feasible methods of restoring the metal lost from the pipe walls to date. Preventing further loss of metal from the pipe walls must become a central objective in managing these pipelines. The focus is to retain the existing thickness for the longest possible time.

The factors that corrode the internal and external pipe walls are different and each requires a unique control strategy. The interior of the pipe is primarily subject to corrosion due to gases released from the sewage. Results in this project indicate that the original coating should not be viewed as a competent barrier to this form of corrosion. The methods commonly employed to control this are providing air release valves at high points to exhaust the gas and keep the pipe full, use of chemicals to prevent the formation or release of the gas, or a combination of both. The external pipe walls also lack a competent coating system to inhibit electrolytic corrosion. Further loss of pipe wall thickness from the exterior can be limited by restoring the functionality of the cathodic protection system.

A system of benchmark sites is required to monitor the success of measures taken to limit internal and external corrosion. This would involve selecting representative locations, selecting appropriate non-destructive testing methods, and scheduling a testing/evaluation program.

It is generally impractical to improve the performance of the soil-pipe system over the entire length of pipelines such as these. However, it may be feasible to improve performance in localized areas with specific loadings such as road crossings. Options include stiffening the pipe, improving the soil properties, or a combination of both.

Successfully implementing any approaches to improve reliability by managing loads or improving the ability of the pipe to resist loads will require a proactive management strategy. Suggestions for how this might be implemented are presented in the following section.

7.3 Preventive Maintenance Activities

The wastewater industry has become increasingly aware that underground infrastructure can no longer be managed in an “out-of-sight out-of-mind” manner. Preventive maintenance activities are crucial to the continued reliability of the SFMs. The following preventive maintenance activities are designed to provide early indications of potential problems with the SFMs:

- Revise CassWorks™ to allow direct entry of force main asset-related work orders to facilitate direct queries of all force main-related work. This would include identification of all appurtenances (e.g. air/vacuum valves), cathodic protection system infrastructure, and benchmark testing sites for wall thickness monitoring. The work order functionality would then be used to generate and track performance of maintenance and monitoring activities along with the resulting data for each.
- Develop and staff a monthly air release/vacuum valve maintenance regime, completed with standard CassWorks™ reporting functions.
- Develop and staff an annual surface survey of the complete SFM alignments to identify potential changes in the pipelines or easement encroachments
- Develop and fund the ability to perform a routine leak detection survey to identify potential pipeline leaks
- Prepare a ‘Sewer Force Main Management Plan’ to capture both routine and emergency management procedures. Emergency management considerations would include:
 - Working with local contractors to identify the key equipment and materials that would be needed to restore service in the event of a pipe failure.
 - Develop a diversion pumping plan for each SFM. Procure and store the recommended key equipment and materials to restore and repair the SFM, and to divert flow around damaged sections during the repair operations.

7.4 Forensic Evaluation Activities

Drainage improvements are currently being planned that will require relocation sections of the two SFMs along Florida Avenue. This is an opportunity to conduct a forensic evaluation of a relatively long section of each pipeline.

When the existing SFMs are abandoned, the Board should complete an in-situ evaluation of the abandoned pipe. The forensic evaluation activities should, at a minimum, include the following observations:

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- Areas around high spots, corporation cocks and air release valves, for signs of interior corrosion or deterioration
- Any specific signs of deterioration at canal crossings
- Anodes and anode connections to the pipe
- Condition of welds and joints
- Adherence of the linings and coatings
- Bedding condition
- Amount of deflection (e.g., amount “out-of-round”)

Particular attention should be paid to sections of pipe installed under roads. These crossings should be evaluated to determine potential deflection caused by the additional loadings associated with the crossing.

The trench zones at these crossings should be evaluated to determine if stabilization of the trench zone would be warranted when future road work is planned along the SFM alignments. Such stabilization measures could be incorporated into the road work projects and provide an extra level of protection for the pipelines.

Similarly, particular attention should be paid to sections of the pipe that cross under rail roads. The condition of the casing pipes should be evaluated for structural integrity and signs of deterioration.

Section 8

Findings, Conclusions and Recommendations

8.1 Findings

The following lists the key findings from the SFM reliability evaluation.

1. Initial design drawings for the two force mains essentially made provisions for both internal and external corrosion via:
 - a. Coal tar/coal tar enamel linings
 - b. Coal tar/coal tar enamel coating along with special additional coatings/wrapping:
 - Cement mortar/gunite layer
 - A coal tar impregnated, asbestos fiberglass wrapping
 - c. Impressed current facilities
 - d. Sacrificial anodes (buried)
 - e. At many high spots:
 - 2-inch manual corporation cocks/stops
 - Manual air/gas release installations
2. In checking the Board records, no major failures or maintenance activities have taken place on either of these force mains.
3. Contract 5075-1 relocated approximately 1,000 feet of the 54-/ 60-inch pipe, but no known evaluation of the 54-/60-inch pipe condition was made when those relocations took place.
4. An overview report of existing conditions was performed by Chester Engineers for the 72-inch and 54-inch force mains after hurricanes Katrina and Rita.
5. Sections of the 54-inch and 72-inch force mains will be relocated by the United States Army Corps of Engineers (USACE) within the next year as part of a canal widening project.
6. Samples of the pipe wall (coupons) were taken at five locations. The measured thickness with calipers compared to the design wall thickness ranges from a 4.1 percent “loss” to a 2.4 percent “gain”. The overall average of all the samples is only 0.7 percent less than the original design thickness. “Gain” represents the actual pipe thickness relative to the design thickness. The actual pipe wall thickness at the time of manufacture can vary from minus 0.01 inches to plus 0.03 inches of the design thickness.
7. Ultrasonic pipe wall thickness measurements were taken at 13 sites. As with the caliper measured coupon thicknesses, the average ultrasonic thickness measurements compared to the design wall thickness ranges from a 6.1 percent “loss” to a 3.2 percent “gain”. The overall average of the samples is only 1.0 percent less than the original design wall thickness.

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8. Guided wave tests to assess the Industrial Canal crossings had limited results due to the interference from bends in the pipelines. The guided wave instances of abnormalities were due to welds rather than an indication of any apparent wall deterioration.
9. Only two of the seven rectifier sites in the cathodic protection system are functional with the most of the others destroyed or damaged during the storms.
10. Cathodic protection system potentials were measured in accordance with NACE SP-0169 with only test Sites R7 and R8 showing any appreciable potential shift. However, these shifts were well under NACE's minimum criteria for potential shift. Thus, the existing cathodic protection systems are not providing effective cathodic protection.
11. Based on a hoop stress analysis using the testing results, the hoop stresses in the pipe wall are very low. Thus, the remaining pipe wall thickness is adequate for the low pressures that are applied.
12. The buckling condition, although no indications of which have been seen in current or past operations, is the most critical structural condition. For all sample sites evaluated for buckling this buckling life has exceeded the factor of safety used by the AWWA M-11 design standard of 2.0. In most sample sites the factor of safety is 1.25 or less under conservative calculation assumptions of a full vacuum condition. Buckling can occur when a vacuum is created when the momentum of flowing liquid is reversed such as at a check valve or following an emergency pump shut down. Since some of the air valves are manually operated, the buckling evaluation in this analysis assumed full vacuum conditions.
13. At deflections greater than 5 percent the pipe lining and coating can disband. At deflections of 20 percent or greater the pipe can fail by inversion. No pipe studied in this project is predicted to reach 20 percent deflection.
14. Soils along the pipeline alignments are "moderately aggressive" to "extremely aggressive for corrosion on steel pipes.
15. The coating system has broken down and is nearing the end of its useful life. The existing coal tar lining and coating system have to date largely protected the steel pipe wall from significant damage, but will provide limited protection in the future.

8.2 Conclusions

1. As designed, these force mains had a minimum service life expectancy of 50 years or more, except for the lack of a designed-in automatic air/vacuum gas release system. Based on review of the samples tested, such life expectancy can be extended for many decades provided the automatic air release valves are modified to add vacuum capabilities (as a buckling precaution) and provided the corrosion control mechanisms are rehabilitated or replaced.
2. Since the findings of this evaluation are based on limited data, a detailed forensic evaluation should be performed on the sections of 54-inch and 72-inch SFMs to be relocated in 6 months to a year. The Board should formally request that the USACE include provisions to ensure the relocation contractor cooperates with the Board's forensic investigations during their removal operations.

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3. Improved record keeping and documentation of pipe investigation and maintenance should help keep these pipelines in service for many decades.

8.3 Recommendations

1. The damaged or deteriorated corrosion control systems should be replaced or refurbished:
 - a. All rectifier installations should be replaced or repaired and allowed to operate at 75 percent of rated capacity for a minimum of two months
 - b. A close interval survey should be conducted to determine the overall protection level on the SFMs based on the refurbished rectifier impressed current system. Additional cathodic protection potential will be required to maintain adequate cathodic potentials due to the increase surface area to be protected due to the breakdown of the existing coating's dielectric capacity.
 - c. A new sacrificial anode system should be installed to replace the destroyed anodes.
2. The exposed cement mortar (gunite) coatings on canal crossings need to be inspected and repaired or replaced, as necessary.
3. All the high spots in the force mains, where curb stops/cocks or manual air release valves are or were installed, need to have automatic air/vacuum valves installed appropriately, and the existing automatic air release valves should be modified to automatic air/vacuum valves.
4. When the planned sections of the 54-inch and 72-inch force mains are replaced for the Florida Avenue Canal improvement project, a detailed forensic evaluation of the “out-of-service” pipe sections should be performed for the following:
 - a. Areas around high spots, corporation cocks and air release valves, for signs of interior corrosion or deterioration
 - b. Any specific signs of deterioration at canal crossings
 - c. Anodes and anode connections to the pipe
 - d. Condition of welds and joints
 - e. Adherence of the linings and coatings
 - f. Bedding condition
 - g. Amount of deflection (e.g., amount “out-of-round”)
5. Since there is some redundant capability from SPS D to the EBWWTP, but currently none from SPS A to SPS D, an evaluation should be performed to see if the old 48-inch force mains to the river from SPS A and SPS D could be interconnected near the river for some level of redundancy.
6. Develop a predictive maintenance procedure for the collection system operators maintain a SFM monitoring database, including:
 - Examination of the interior of each pipeline, including the Industrial Canal crossing, on a regular basis (every 2 to 5 years) using an interior leak detection

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technology such as the “Smart Ball” or “Sahara” systems. The initial inspection will define the baseline conditions for leak locations.

- Maintain a database of information from SFM monitoring program including:
 - Leak location by stations
 - Locations of leak repairs
 - Pipe condition and assessment at unscheduled excavations such as utility repairs and other SFM work
 - Provide complete condition assessment on the sections of 54-inch and 72-inch SFMs to be replaced under USACE contract as discussed in item 8.2.2 of this Section
 - Compile yearly cathodic protection system readings and maintenance reports
 - Develop a training program for operations staff defining the requirements of the database and monitoring program
 - Perform stray current analysis along the pipelines on an annual basis to locate areas of high corrosion potential.
 - Document other existing or new utilities with corrosion protection systems within the area of the two SFMs that could affect the function of the SFMs cathodic protection systems
 - Link the database to any existing GIS systems to allow visual interpretation of the data
 - Perform ultrasonic thickness testing as necessary in areas of the SFMs that experience high rates of leaks or repairs
7. Prepare a ‘Sewer Force Main Management Plan’ to capture both routine and emergency management procedures. Emergency management considerations would include:
- Working with local contractors to identify the key equipment and materials that would be needed to restore service in the event of a pipe failure.
 - Develop a diversion pumping plan for each SFM. Procure and store the recommended key equipment and materials to restore and repair the SFM, and to divert flow around damaged sections during the repair operations.

Installation of automatic air/vacuum valves, repairs to the corrosion protection system, and establishment of a pipe condition monitoring program for the SFMs will assist in extending the remaining service life of the SFMs and reduce future capital cost to the Board.

Appendix A

Historical Design Information

Design Data Sources

The 54-/60-inch and 66-/72-inch force mains serving SPS D and SPS A have been in operation since the mid 1960s and mid 1970s, respectively. The initial data sources for the SFM investigation are the S&WB's available plan, profile and as-built drawings. The City's water and sewer location maps include references to construction contracts and construction books that correspond to each water, sewer or sewer force main project. The following sources of initial construction data were identified from the preliminary work performed by Chester Engineers to and expanded as a part of this SFM evaluation. The initial design data included:

- Contract 3056, Drawing 6875-S (66"/72")
- Contract 3057A, Drawing 6870-S (66")
- Contract 3057B, Drawing 6871-S (66"/72", some 54" rework)
- Contract 432-S, Drawing 5984-G-8 (60")
- Contract 472-S, Drawing 6148-G-13 (54")
- Contract 5075-1, Drawing 11404-W-27 (Partial) (Relocation of 54" West Side Industrial Canal)
- Construction Book Number 3467, pages 10 to 71
- Construction Book Number 3468, pages 38 to 53
- Specifications for Contract 472-S

Contract 3056

Contract 3056 (mid-1970s) included construction of the first 4 miles or so of the 66-/72-inch steel force main between SPS A and the Industrial Canal. This section of the pipeline travels northwest from SPS A, then extends northeast along North Claiborne Avenue and I-10 until reaching Florida Avenue. From that point the force main runs east along Florida Avenue towards the Industrial Canal.

Beginning with Contract 3056, two 48-inch discharge lines from SPS A combine to form a short 60-inch diameter pipeline. After a 60-inch ball valve, the force main increases to a 72-inch diameter pipeline. The pipeline remains this size for about 4,800 feet until reaching the St. Bernard Avenue box canal (covered) crossing, where the pipe splits into two 48-inch diameter lines. After this canal crossing, the dual pipes join back together and become a single 72-inch diameter pipe for the remainder of the contract.

A second 60-inch ball valve is located on the pipeline in the vicinity of SPS D (between Peoples Avenue and Peoples Avenue Canal). Just before the ball valve, there is a tee connection to 60-inch force main that parallels the 72-inch force main. The 60-inch pipe later reduces to a 54-inch pipe and extends all the way to the EBWWTP. A 48-inch line with a 36-inch ball valve provides a connection between these two large diameter parallel force mains. This 48-inch interconnection

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just downstream of SPS D enables diversion of sewage flow from either of the parallel force mains (66-/72-inch and 54-/60-inch) into the other force main.

The as-built construction drawings for Contract 3056 show a cathodic protection system was installed with the steel force main to enhance its longevity and reliability. The cathodic protection system included rectifier deep ground beds and test points, additional test points on posts or in hand holes, and magnesium anodes installed at periodic (roughly 650-foot) intervals along the force main route. A coal tar coating was applied to the interior and exterior surfaces of the steel pipe to provide additional corrosion protection. The exterior coal tar coating was also wrapped in fiberglass asbestos felt to protect the exterior coating from being damaged. The full extent of the felt wrapping was not clear in the drawings.

The force mains are equipped with access manholes at periodic intervals. A typical access manhole consists of a 20-inch diameter pipe section welded to the top of the pipeline and provided with a blind flange. Access to the force main is accomplished by removing the bolts between the flanged opening and the blind flange.

This entry into the pipe is within a standard S&WB manhole with a frame and cover at the ground surface. In some cases the blind flange will have a 2-inch corporation cock or a 4-inch air bleeder valve assembly attached.

The force main is also equipped with a large number of air bleeder valve assemblies situated at locations where gas could collect in the line. The bleeder valve assemblies are mounted on welded access manholes and consist of a 4-inch steel pipe connection, a gate valve or angle valve and a drain line. The manual gate valve or angle valve can be used to bleed off air that collects at the top of the force main piping during normal operations. Initially, there were no automatic air release valves installed on this section of force main, but have been added at a few locations.

Additional exterior protection was afforded the above ground portions of the pipeline by applying a 2-inch cement mortar (gunite) coating on top of the normal coating. This additional coating was also applied to pipeline sections going through casing pipes.

Contract 3057A

Drawings for Contract 3057A were not initially located in the S&WB files, but were subsequently found based on information contained in notes on the S&WB Location Maps 419 and 439. Contract 3057A includes additional construction of the 72-inch and 66-inch steel force main. The 72-inch pipe approaches the Industrial Canal and reduces to a 66-inch diameter pipe where it crosses under the canal. Once the canal crossing is complete, the 66-inch increases back to a 72-inch diameter pipe again. The total length of the force main constructed under Contract 3057A is estimated to total 2,950 feet in length.

Contract 3057A construction drawings indicate that this section of the 66-/72-inch force main goes from Kentucky Street on the west to past Tennessee Street on the east along Florida Avenue and across the Industrial Canal. It matches up with the pipe installed under Contract 3056 to the west and with Contract 3057B to the east. The pipeline reduces from a 72-inch to a 66-inch, 0.375-inch wall thickness, steel pipeline at Kentucky Street and Florida Avenue. Once across the levee, the pipe wall thickness changes to 0.75-inch wall thickness. In addition to the wall thickness change under the Industrial Canal crossing, a 2-inch concrete protective coating is applied over the standard coal tar coating. This concrete coating applies from the west bank to the top of the levee on the east bank. This same concrete coating is added where the pipeline

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crosses the Jordan Canal and the Florida Avenue Canal. The 66-inch portion of the pipeline goes back to 72-inch after crossing the Florida Canal east of the Industrial Canal. Two-inch corporation cocks were provided at the levee crossings and a manual air release valve at the Jordan Canal crossing. The pipeline crosses roughly 50 feet below the water level in the Industrial Canal. The pipe is buried in a trench under the canal bottom with shell backfill around and over the pipe (2 feet of shell cover). Other trench details show 9 inches of river sand under and 2 feet deep in haunch area.

Only one detail in this set of Contract Drawings shows any “fiberglass asbestos felt” wrapping. That reference is only on Sheet 13 and is solely for the 72-inch Pipe Cradle in Saddle for the Florida Avenue Canal crossing. Whether specifications required similar wrapping on the rest of the pipe under this contract is not known.

Contract 3057B

Contract 3057B included construction of the 66-/72-inch steel force main between the Industrial Canal and the EBWWTP. This 72-inch pipe section is located along the north side of Florida Avenue. It extends east towards the EBWWTP before the final leg of the force main turns north to enter the plant site. The total length constructed under Contract 3057B is approximately 7,000 feet, or about 1.3 miles. The last 1,200 feet of the force main approaching the EBWWTP is 66-inches in diameter and crosses a swamp area.

The as-built construction drawings for Contract 3057B shows the same type of cathodic protection system installed as described under Contract 3056 above. Similarly, Contract 3057B shows a hot applied coal tar coating and lining as applied under Contract 3056 was also applied to this section of the force main. It is believed that a fiberglass asbestos felt wrapping may have been applied to the underground piping and a 2-inch thick cement coating may have been applied to the above ground piping to protect the coal tar exterior coating. There are no details on the drawings indicating the fiberglass asbestos felt as per the prior contract, but such may have been specified.

This section of the force main was equipped with a single access manhole located near the EBWWTP. The access manhole detail was the same as previous contract descriptions. Both the 66- and 72-inch diameter sections of this portion of the force main are shown with 0.375-inch wall thickness, coal tar lining and coating is also specified on the drawings. At the Florida Avenue Canal/Railroad/Levee/and Swamp crossings, a 2-inch concrete coating is applied over the coal tar coating.

The typical bedding is river sand 9 inches below the pipe to 2 feet above pipe bottom with select backfill material to the surface. In the swamp crossing area the trench is a lumber base (mud sills) for 4 inches, 8 inches of shell bedding between pipe bottom and lumber trench bottom, 2 feet of shell bedding in the haunch area and select backfill to the ground surface. As a hedge against the ground conditions issue, double full fillet welded joints were shown on the drawings from south of the Railroad crossing across the swamp to the south EBWWTP levee.

Normal welds on the 66-/72-inch force main were typical butt welds on spool pieces and double fillet welds on lap joints/bell and spigot joints. Where 66-inch diameter pipe 0.375-inch thick was used under the Industrial Canal, a full but weld was called for with a minimum gap of 1/64th inch and maximum gap of 1/32nd inch. The full depth butt weld was a 60° angle (balanced) beginning 1/16th of an inch from the pipe wall. On sections of lap joint/bell and spigot pipe not

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under swamp or the Industrial Canal, only a sealing weld was required for the exterior weld with a full fillet weld on the inside of the pipe.

Contract 432-S

Contract 432-S covers the 60-inch section of force main from SPS D to Metropolitan Street along the Florida Avenue corridor. This section of the 54-/60-inch pipe has numerous street and canal crossings. The 60-inch section of force main connects to an existing 50-inch force main from the north and the combined flow goes easterly to the EBWWTP.

From SPS D the 54-inch pipe expands to 60-inch with an access manhole prior to crossing a Railroad Track Spur and Almonaster Avenue. In this initial stretch of pipe the lining is coal tar enamel, but the coating is shown to be only 2-inch cement mortar. After crossing Almonaster Avenue the pipe has an insulated closure piece and keeps the coal tar enamel lining, but switches to an exterior wrap of coal-tar asbestos felt fiberglass. The pipe thence goes over the open channel type Peoples Avenue Canal and has an additional exterior coating of 2-inch cement mortar. Continuing southeast, it crosses under several railroad lines in casings using both coal tar coating and cement mortar exterior encasement. At Press Street the 60-inch pipe crosses under a 30-inch storm drain line. The 60-inch pipe continues to dip to cross under storm drain lines at Feliciana and Clouet Streets. At Metropolitan Street the 60-inch pipe connects to an existing 50-inch force main from the north. The combination of these force mains continues southeast along Florida Avenue corridor as was constructed under Contract No. 472-S. All references to pipe wall thickness along this section of SFM is 0.375-inch.

Contract 472-S

Contract 472-S covers the 54-inch section of the force main from Metropolitan Street along Florida Avenue to the then existing Florida Avenue Levee crossing leading to the EBWWTP. The drawings indicate that the Industrial Canal section of the 54-inch force main was under construction via a separate contract. Even though not part of this contract, the plan and profile of the pipeline design across the Industrial Canal was included on these drawings.

From where the 60-inch pipe from SPS D joins with the 50-inch pipe from the north, there is a reducer to a 36-inch valve and then an increaser to 54-inch that carries forward to the EBWWTP along the Florida Avenue corridor. The area west of the Industrial Canal has several drainage crossings where the force main goes under cross drainage pipes: this occurs at Louisa Street, Desire Street (concrete box canal), Gullier Street, Pauline Street, Alvar Street and Mangant Street. The pipe thickness continues at 0.375-inch with coal tar lining and coating until reaching the Railroad crossing west of France Road; thence the thickness changes to 0.5-inch for the crossing under the railroad. On the east side of France Road a 12-inch side outlet was constructed with a 12-inch valve located in a manhole on the north side of the pipeline. Pipe thickness remains at 0.375-inch with coal tar lining and coating. About 1,000 to 1,200 feet of the force main between France Road and the West Industrial Canal levee was rebuilt in 1978/1979; which included the Florida Avenue Canal crossing. Initially the pipeline stayed on the north side of the Florida Avenue Canal until a few hundred feet from the West Levee crossing. The pipe thickness changed to 0.5-inch for the Florida Avenue Canal crossing through the Industrial Canal Crossing. The above grade Florida Avenue Canal crossing had an added 1.5-inch thick mortar coating on the above grade crossing section. The revision to this section of SFM in 1978/1979 will be discussed in the following Contract 5075-1 section.

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The Industrial Canal crossing is shown to have 0.75-inch wall thickness, coal tar lining and coating with 2.5-inch thick cement mortar coating. The depth of the pipe is at -31.80 feet compared to the top of the east levee of +30.6 feet. Normal top of water level in the canal is +21 feet on the survey basis (not +21 feet above sea level).

As the SFM crosses the east Industrial Canal levee, the 54-inch pipe wall thickness drops to 0.5-inch with a 1.5-inch cement mortar coating over coal tar lined and coated pipe. A 2-inch corporation cock was installed at the top of the east levee crossing.

Going easterly from the east levee the 3/8-inch thick coal tar lined and coated force main crosses the Jordan Avenue box canal and is further coated with 1.5-inches of cement mortar. The SFM crosses under four drainage pipes: one at Tennessee Street, one at Forstall Street, one at Andry Street and one at Caffin Street. The last three of these crossings were modified when the 72-inch force main was constructed under Contract 3057-B (see previous section covering Contract 3057-B). At Tupelo Street the 54-inch crosses under a box canal. This force main crossing remained in the same location under the canal, but a 20-inch air/gas relief pipe was constructed across the top of the box canal under Contract 3057-B. At Dubreuil Street the SFM was constructed under the cross drainage pipe. The pipe remains at 0.375-inch thick with coal tar lining and coating. A welding detail could not be found on this contract set of drawings, but specifications call for the ends of all 54-inch diameter pipe sections to be beveled for inside butt-welded field joints.

After crossing Dubreuil Street, the force main continues east for about one block and then turns northerly to re-cross the Florida Avenue Canal on towards the EBWWTP. In the northerly direction to the plant there is a valve installation and an “Insulator Pipe Section” prior to the Florida Avenue Canal recrossing; which is part of a separate contract the rest of the way to the EBWWTP. The 0.375-inch thick pipe continues to be coal tar coated and lined until it reaches the Insulator Pipe Section and thence the exterior coating is only 2-inch mortar coating. The construction drawings for the last section of the SFM from south of the Florida Avenue Canal crossing into the EBWWTP were not found during this study. However, drawings for Contract 5075-1, which involved the rerouting of a section of the SFM from west of the west Industrial Canal going west about 1,000 feet and which required a new Florida Avenue Canal crossing, were found and are described below.

Contract 5075-1

Contract 5075-1 covers the relocation of roughly a thousand foot section of the 54-inch force main just east of the Industrial Canal and the relocation of the Florida Avenue Canal crossing. Due to major drainage improvements to the Florida Avenue Canal and the drainage pump station in 1978/1979, a section of the 54-inch pipeline had to be redone. The original pipeline was not relocated. New facilities were designed and constructed, connected to the existing pipeline and then the old section of pipe was removed.

This new section of force main is 0.375-inch thick steel wall with coal tar lining and coating. Where the new Florida Avenue Canal crossing was constructed, a 2-inch thick cement mortar coating was applied to the pipe. A 2-inch corporation cock was installed on the top downstream area of the crossing. There is no indication on the drawings of any fiberglass asbestos wrap that had shown up on prior contract drawings, but such may have been specified. The typical bedding consists of 9 inches of river sand under the pipe, 2 feet of river sand under the haunches, and select backfill to the trench surface. Several anodes were installed on the new pipe for corrosion

Appendix A – Historical Design Information

control. The typical field welded joint calls for a full butt weld with a 60° weld angle and a minimum gap between the pipe sections of 1/64th inch and a maximum of 1/32nd inch.

Contract 3057-B

Contract 3057-B is primarily for the installation of the 72-inch pipeline; however; several key issues were addressed related to the existing 54-inch pipeline along Florida Avenue. Conflict structures were constructed at Coffin Avenue and at Andy Street to remove dips in the 54-inch force main where it went under existing storm drainage facilities. The new short sections of pipe (less than 50 feet) are 0.375-inch wall thickness, with hot applied coal tar lining and coating, and with an additional 2-inch mortar coating. Also, at Forstall Street, a dip in the 54-inch force main was eliminated by diverting the storm drain pipe. The same coating and lining as per the installations at Coffin and Andy.

At Tupelo Avenue intersection with Florida Avenue the initial 54-inch pipeline installation went under the 14 foot wide (box culvert type) canal in Tupelo Avenue, without provision for any air/gas release valves. To avoid trapped air/gas or release of gas at this location, a 20-inch pipeline was tapped into the top of the 54-inch pipe both upstream and downstream of the canal with the new 0.375-inch thick 20-inch pipeline crossing over the top of this box culvert type canal.

Construction Book Information

Construction Book 3467 contains information for Contracts 3056 and 3057A. Construction Book 3468 contains information for Contract 3057B. Construction Book 3467 could not be located in S&WB files.

Construction Book 3468 contains sketches of the pipelines and appurtenances constructed under both Contracts 3056 and 3057B.

Soils Investigations

During initial planning for the 72-inch SFM, the S&WB conducted a soils investigation, the results of which were presented in Subsoil Investigation Proposed 72-inch Diameter Sewer Force Main, Gore Engineering, Inc., March 1975, and in Subsoil Investigation, Sewerage & Water Board of New Orleans, Florida Avenue Canal Closure Tupelo Street to St. Bernard Parish Line, New Orleans, Louisiana, Gore Engineering, March 1970, with supplemental information provided in April 1975. The investigation included drilling of soil test borings to determine subsurface conditions and stratification along the proposed force main alignment. Laboratory tests were performed on the samples obtained from the borings to evaluate their physical characteristics and engineering analyses were made based on the borings and test data. A total of 37 soil test bores, ranging in depth from 30 and 40 feet along the general alignment to 75 feet where the force main was planned to cross existing major culverts and canals, were drilled.

At depths between about 5 and 20 feet, the pipes would be located within the very soft to soft alluvial clays with strengths generally less than 40 kiloPascal (kPa), with an average strength approx 20 kPa. Based on this, a Spangler modulus of between 1 and 2 megaNewton per square meter (MN/m²) was considered acceptable for design purposes. The soil unit weight assigned was approximately 14 to 15 kiloNewton per cubic meter (kN/m³). This material was not considered to be appropriate for use as pipe bedding material due to its low strength and high organic content.

Appendix A – Historical Design Information

Due to the weak soils identified by the soils reports, the portions of the pipeline were laid on wooden planks with 6-inches of shells and backfilled with sand to above the pipeline. The excavation was typically supported with wood sheets left in place.

As discussed in various design contract drawings and specifications, both SFMs were protected from the adverse impacts of external corrosion with an external coal tar coating with at least portions and possibly all of the underground pipes were wrapped with a fiberglass asbestos felt wrapping to protect the coal tar coating. The above ground portions of the piping and the pipeline sections going through casing pipes were encased with a 2-inch cement mortar (gunite) coating to protect the coal tar coating.

Additional corrosion protections was provided by a cathodic protection system installed with the SFMs that included rectifier deep ground beds and test points, additional test points on posts or in hand holes, and magnesium anodes installed at 650-foot intervals along the force main route.

Sewer Pump Station Data Sources

The Pump Station Testing and Evaluation Report, August 1997 (Exhibit 7 of the Consent Decree), provides a detailed description of each of the 66 pump stations then operated and maintained by the S&WB along with an assessment of their condition and performance. SPS A and SPS D are two of the key stations within the New Orleans sewer system. The following description of SPS A and SPS D is from the Corrective Action Plan for the East Bank Wastewater Collection System, July 2000. Based on post Katrina evaluations, modifications will need to be made in the Connective Action Plan.

Sewer Pump Station A

SPS A is a large regional pumping station that handles all of the flow from the Carrollton, Uptown, Central Business District (CBD) and Mid-City basins. It contains a total of six pumps of which only two usually operate in combination at a time during dry weather. Two vertically-aligned pumps are powered by 1,250 horsepower (hp) motors, while four horizontally-aligned pumps are powered by two 2,300 hp motors (two pumps powered by each motor).

As noted in the Corrective Action Plan for the East Bank Wastewater Collection System pre-Katrina report, SPS A re-pumps flow from Stations 1, 3, 5, 6, 8 14 and 15 in addition to its own 7.4 square mile service area. This equates to an overall contributing service area of approximately 19.8 square miles. During dry weather, SPS A pumped approximately 58 mgd in pre-Katrina flows. Of this amount, approximately 21 mgd was contributed by the SPS A service area and the remaining 37 mgd (64 percent) was re-pumped flow from the other stations. SPS A pumps all of its flow directly to the EBWWTP through the 72-inch SFM.

Sewer Pump Station D

SPS D, like SPS A, is a large regional pump station that handles most of the flow from the Lakeview and Gentilly basins. It contains three pumps of which only one normally operates during dry weather. The vertically-aligned pump, normally operated alone during dry weather, is powered by a 275 hp motor. Two horizontally-aligned pumps are powered by a 2,500 hp motor (two pumps powered by single large motor).

As noted in the Corrective Action Plan for the East Bank Wastewater Collection System pre-Katrina report, in addition to its own 2.1 square mile service area, SPS D re-pumps flow from

Appendix A – Historical Design Information

Stations 4, 9, 17, 18, 19, 20, 21, 22, Lakewood South and City Park. This equates to an overall contributing service area of approximately 16.3 square miles. During dry weather SPS D pumped approximately 22 mgd in pre-Katrina flows. Of this amount, approximately 3 mgd was contributed by the SPS D service area and the remaining 19 mgd (86 percent) was re-pumped flow from the other stations. SPS D pumps all of its flow directly to the EBWWTP through the 54-/60-inch SFM. The 54-inch SFM interconnects with the 72-inch SFM from SPS A just downstream of SPS D. The interconnecting valves are normally closed.

SPSs A and D Flow to EBWWTP

As noted in the Corrective Action Plan for the East Bank Wastewater Collection System report, re-pumped flow from various pump stations accounted for approximately 60 mgd, or 55 percent, of the total DWF at the EBWWTP. The S&WB's capacity upgrade strategy pre Katrina was to reduce large pump station service areas and to eliminate re-pumping of wastewater when possible. Recommendations to accomplish these goals was for SPS A to serve only its immediate service area and no longer re-pump flow from other stations and for SPS D to no longer re-pump flow from Pump Station 17. Combined with modifications to allow several other stations to pump only their service area flows, the re-pumped flows tributary to EBWWTP would have been reduced from 55 percent of dry weather flow (DWF) to 11 percent of DWF.

After the recommended capacity modifications, the service area for SPS A would have been reduced by 63 percent and the average DWF would have been from approximately 58 mgd to 21 mgd; also, a reduction of almost two-thirds. This would have been accomplished by discharging flow from Stations 1, 3, 5, 6, 8, 14 and 15 into force mains connected to the 72-inch downstream of SPS A rather than flow through gravity lines to SPS A.

Similarly, the service area for SPS D would have been reduced approximately 22 percent and average DWF would have dropped from approximately 22 mgd to 17 mgd, a reduction of 23 percent. This would have been accomplished by connecting to and enhancing the force main network to no longer re-pump flow from Station 17 through SPS D.

Appendix B

Surface Inspection Photographs



Location 1A at East Bank WWTP

Non Destructive Ultrasonic Testing (above grade) near EBWWTP 66-inch SFM



Location 1A at East Bank WWTP

Non Destructive Ultrasonic Testing (above grade) near EBWWTP 66-inch SFM



Location 1B at East Bank WWTP

Non Destructive Ultrasonic Testing (above grade) at EBWWTP Levee
Crossing 54-inch SFM



Location 1B at East Bank WWTP

Non Destructive Ultrasonic Testing (above grade) at EBWWTP Levee
Crossing 54-inch SFM

Appendix B – Surface Inspection Photographs



Location 1C at East Bank WWTP
Coupon Retrieval (below grade) on 66-inch SFM



Location 1C at East Bank WWTP
Coupon Retrieval (below grade) on 66-inch SFM

Appendix B – Surface Inspection Photographs



Coal tar coating 50% gone

Coupon 1C at East Bank WWTP

Coupon Retrieval (below grade) on 66-inch SFM



Location 1D at East Bank WWTP

Coupon Retrieval (inside valve box) for 54-inch SFM

Appendix B – Surface Inspection Photographs



Location 1D at East Bank WWTP
Coupon Retrieval (inside valve box) for 54-inch SFM



Exterior



Interior

One pit 0.030" deep

Coupon 1D at East Bank WWTP
Coupon Retrieval (below grade) on 54-inch SFM

Appendix B – Surface Inspection Photographs



Locations 2A and 2B East of the Industrial Canal

Non Destructive Testing Guided Wave (above grade) 66-inch and 54-inch SFMs.
Water line between two SFMs.



Location 2B East of the Industrial Canal

Guided Wave (above grade) 54-inch SFMs

Appendix B – Surface Inspection Photographs



Location 3A West of the Industrial Canal

Coupon Retrieval (above grade) 54-inch SFM



Location 3A West of the Industrial Canal

Coupon Retrieval (above grade) 54-inch SFM

Appendix B – Surface Inspection Photographs



Coupon 3A West of the Industrial Canal

Coupon Retrieval (above grade) 54-inch SFM



Location 4A Florida Avenue Canal Crossing

Non Destructive Ultrasonic Testing (above grade) 72-inch SFM

Appendix B – Surface Inspection Photographs



Location 4A Florida Avenue Canal Crossing

Non Destructive Ultrasonic Testing (above grade) 72-inch SFM.



Location 4B Florida Avenue Canal Crossing

Non Destructive Ultrasonic Testing (above grade) 54-inch SFM

Appendix B – Surface Inspection Photographs



Location 4B Florida Avenue Canal Crossing

Non Destructive Ultrasonic Testing (above grade) 54-inch SFM



Location 5A Peoples Ave near SPS D

Coupon Retrieval (above grade) 72-inch SFM

Appendix B – Surface Inspection Photographs



Location 5A Peoples Avenue near SPS D

Coupon Retrieval (above grade) 72-inch SFM



No corrosion

Coupon 5A Peoples Avenue near SPS D

Coupon Retrieval (above grade) 72-inch SFM

Appendix B – Surface Inspection Photographs



Location 5B Peoples Avenue near SPS D

Coupon Retrieval (above grade) 60-inch SFM



Location 5B Peoples Avenue near SPS D

Coupon Retrieval (above grade) 60-inch SFM

Appendix B – Surface Inspection Photographs



Coupon 5B Peoples Avenue near SPS D

Coupon Retrieval (above grade) 60-inch SFM



Location 6A across Peoples Avenue from SPS D

Non Destructive Ultrasonic Testing 60-inch SFM



Location 6A across Peoples Avenue from SPS D

Non Destructive Ultrasonic Testing 60-inch SFM



Location 7A St. Bernard Avenue Box Culvert Crossing

Non Destructive Ultrasonic Testing (below grade) two 48-inch SFMs crossing the box culvert in the median. The SFMs are only 1 foot below grade and are cut into the top of the box culvert.

Appendix B – Surface Inspection Photographs



Location 7A St. Bernard Avenue Box Culvert Crossing

Non Destructive Ultrasonic Testing (below grade) two 48-inch SFMs crossing the box culvert in the median. The SFMs are only 1 foot below grade and are cut into the top of the box culvert.



Location 8A behind Fire Station near I-10

Non Destructive Ultrasonic Testing (below grade)



Location 8A behind Fire Station near I-10

Non Destructive Ultrasonic Testing (below grade)

Appendix C

Soils Test Results

LABORATORY ELECTROLYTE ANALYSIS									
CLIENT: MWH Americas, Inc.					ENGINEER: James Brandt				
PROJECT: Sewer Force Main Sites					TECHNICIAN: Nancy Jacob				
OFFICE: Belle Chasse					DATE RECEIVED: 09/01/2009 & 09/14/2009 & 09/23/2009				
JOB #: 332862					DATE OUT: 09/04/2009 & 09/21/2009 & 09/24/2009				
SET-1									
						Calculated			
SAMPLE ID	MOISTURE %	pH	CHLORIDE ppm	SULFIDE ppm	CONDUCTIVITY \square mhos	RESISTIVITY ohm-cm	SAMPLE TYPE	SAMPLE COLOR	Comments
(1) 1 -- A	18.00	7.6	6	0	390	2,600	Clay-loam	Gray	Very Corrosive
(2) 1 -- B	14.00	8.1	6	0	310	3,200	Clay-loam	Gray	Very Corrosive
(3) 2 -- A	18.00	8.4	10	0	490	2,000	Clay	Gray & brown	Very Corrosive
(4) 2 -- B	17.00	7.9	10	0	460	2,200	Clay-loam	Gray & brown	Very Corrosive
SET-2									
						Calculated			
SAMPLE ID	MOISTURE %	pH	CHLORIDE ppm	SULFIDE ppm	CONDUCTIVITY \square mhos	RESISTIVITY ohm-cm	SAMPLE TYPE	SAMPLE COLOR	Comments
(5) 1 -- C	26.00	7.9	240	0	1,700	590	Clay	Gray & brown	Extremely Corrosive
(6) 1 -- D	53.00	7.6	20	0	1,400	710	Clay	Gray & brown	Extremely Corrosive
(7) 6 -- A	39.00	7.4	36	0	930	1,100	Clay	Gray	Very Corrosive
(8) 7 -- A	5.00	8.2	1	0	200	5,000	Sand	Gray & brown	Corrosive
(9) 8 -- A	6.90	7.7	4	0	130	7,700	Sand	Light brown	Moderately Corrosive
SET-3									
						Calculated			
SAMPLE ID	MOISTURE %	pH	CHLORIDE ppm	SULFIDE ppm	CONDUCTIVITY \square mhos	RESISTIVITY ohm-cm	SAMPLE TYPE	SAMPLE COLOR	Comments
(10) 3 -- A	35.00	8.0	8	0	880	1,100	Clay	Gray-brown	Very Corrosive
(11) 4 -- A	53.00	7.7	12	0	1,000	1,000	Clay	Gray-brown	Very Corrosive
(12) 4 -- B	34.00	8.0	12	0	950	1,100	Clay	Gray-brown	Very Corrosive
(13) 5 -- A	6.80	7.7	9	0	620	1,600	Sandy loam & rocks	Gray-brown	Very Corrosive
(14) 5 -- B	30.00	7.5	2	0	500	2,000	Clay loam	Gray-brown	Very Corrosive

Appendix D

Lining/Coating Test Results



ITEM: Site 1-A

LOCATION: EBWWTP between Levee and Rail Road track.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8",
Interlayer: 4 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No pull complete failure.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in poor condition. The coating has very little adhesion properties. It seem as if the coating has reached its life expectancy and is in the process of breaking down. Some minor to moderate surface corrosion present.



ITEM: Site 1-B

LOCATION: EBWWTP between Levee and Rail Road track.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

No coating present.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No testing conducted.

COMMENTS:

Following the removal of the gunite, the entire 4' x 4' area has no coating present and only light to moderate surface corrosion covers the area. No major pitting present.

Appendix D – Lining/Coating Test Results



ITEM: Site 1-C

LOCATION: EBWW TP.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 4 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No adhesion test conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Visual inspection show that the coating condition is extremely poor. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection no pitting located and very minor surface corrosion present.

Note: Original picture file was corrupted and during a return visit the picture was re-taken.



ITEM: Site 1-D

LOCATION: Various Locations.

COATING: N/A.

CONDITION: N/A.

COATING DFT:

Felt Wrap/Hot Applied Tar: N/A..
Interlayer: N/A.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No Adhesion Test Conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the abatement crew removed all the coating prior to the visual inspection being conducted. Surface are had moderate surface corrosion present.

Appendix D – Lining/Coating Test Results



ITEM: Site 2-A

LOCATION: Florida Ave. and Surekote at Industrial Canal.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 6.5 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No pull complete failure.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in poor condition. The coating has very little to no adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection some minor pitting was located at an intersecting girth and horizontal weld.



ITEM: Site 2-B

LOCATION: Florida Ave. and Surekote at Industrial Canal.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 6.5 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No pull complete failure.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in poor condition. The coating has very little to no adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection some minor pitting was located on one of the girth welds.



Appendix D – Lining/Coating Test Results



ITEM: Site 3-A

LOCATION: Florida Ave. at Industrial Canal.

COATING: Hot applied coal tar / felt wrap.

CONDITON: Moderate.

COATING DFT:

Felt Wrap/Hot Applied Tar: Coating removed prior to inspection.
Interlayer: 6.5 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No pull complete failure.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in moderate condition. The coating has very little to no adhesion properties. It appears the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection only minor surface corrosion was present.



ITEM: Site 4-A

LOCATION: Florida Ave. at Canal Crossing.

COATING: Hot applied coal tar / felt wrap.

CONDITON: Moderate.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 6 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No adhesion test conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in moderate condition. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection no pitting located and very minor surface corrosion present.

Note: Original picture file was corrupted and during a return visit the picture was re-taken.

Appendix D – Lining/Coating Test Results



ITEM: Site 4-B

LOCATION: Florida Ave. at Canal Crossing.

COATING: Hot applied coal tar / felt wrap.

CONDITON: Moderate.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 6 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No adhesion test conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in moderate condition. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection no pitting located and very minor surface corrosion present.

Note: Original picture file was corrupted and during a return visit the picture was re-taken.



ITEM: Site 5-A

LOCATION: Florida Ave. and Rail Road Tracks.

COATING: Hot applied coal tar / felt wrap.

CONDITON: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".
Interlayer: 6 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

Dolly pulled at 50 lb.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in poor condition. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection no pitting located and very minor surface corrosion present.

Appendix D – Lining/Coating Test Results



ITEM: Site 5-B

LOCATION: Florida Ave. and Rail Road Tracks.

COATING: Hot applied coal tar / felt wrap.

CONDITION: Poor.

COATING DFT:

Felt Wrap/Hot Applied Tar: 1/8"-1/4".

Interlayer: 4 mil.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

Dolly pulled at 700 lb.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the coating appears to be in poor condition. The coating has very little adhesion properties. It seems as if the coating has reached its life expectancy and is in the process of breaking down. During the visual inspection some major pitting and surface corrosion was located from the top of the vent migrating down to the bottom of the piping. It appears to be due to a leaking vent located at the top on the pipe.



ITEM: Site 6-A

LOCATION: Various Locations.

COATING: N/A.

CONDITION: N/A.

COATING DFT:

Felt Wrap/Hot Applied Tar: N/A.

Interlayer: N/A.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

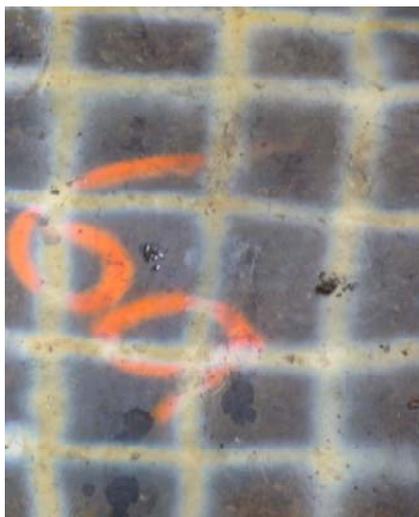
No Adhesion Test Conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

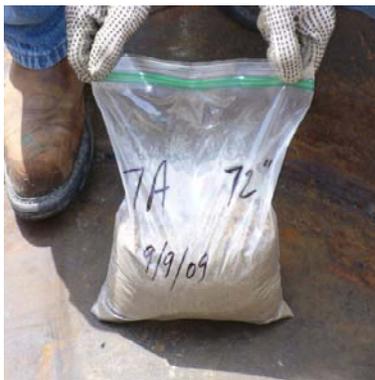
Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the abatement crew removed all the coating prior to the visual inspection being conducted. Surface are had minor surface corrosion present.



Appendix D – Lining/Coating Test Results



ITEM: Site 7-A

LOCATION: Various Locations.

COATING: N/A.

CONDITION: N/A.

COATING DFT:

Felt Wrap/Hot Applied Tar: N/A.
Interlayer: N/A.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No Adhesion Test Conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the abatement crew removed all the coating prior to the visual inspection being conducted. Surface are had minor surface corrosion present.



ITEM: Site 8-A

LOCATION: Various Locations.

COATING: N/A.

CONDITION: N/A.

COATING DFT:

Felt Wrap/Hot Applied Tar: N/A.
Interlayer: N/A.

Note: All dry film thickness reading taken in accordance with SSPC-PA-2.

Micro Test FM SN-39595.

ADHESION TEST RESULTS:

No Adhesion Test Conducted.

Note: Destructive adhesion testing conducted in accordance with ASTM Standard 4541-09.

Elcometer 108 SN HB008N.

COMMENTS:

Following the removal of the gunite, the abatement crew removed all the coating prior to the visual inspection being conducted. Surface are had minor surface corrosion present.

Appendix E

Coupon Extraction Photographs



Exterior



Interior

Coupon 1C 66" inside EBWWTP



Exterior, Angle



Interior, Angle

Coupon 1C 66" inside EBWWTP

Appendix E – Coupon Extraction Photographs



Exterior



Interior

Coupon 1D 54" x 48" reducer inside valve box EBWWTP



Exterior, Angle



Interior, Angle

Coupon 1D 54" x 48" reducer inside valve box EBWWTP



Exterior



Interior

Coupon 3A 54" West of Industrial Canal

Appendix E – Coupon Extraction Photographs



Exterior, Angle



Interior, Angle

Coupon 3A 54" West Of Industrial Canal



Exterior



Interior

Coupon 5A 72" on Peoples near SPS D



Exterior, Angle



Interior, Angle

Coupon 5A 72" on Peoples near SPS D

Appendix E – Coupon Extraction Photographs



Exterior



Interior

Coupon 5B 60" on Peoples near SPS D



Exterior, Angle



Interior, Angle

Coupon 5B 60" on Peoples near SPS D

Appendix F Coupon Test Results



Lehigh Testing Laboratories, Inc.

A Subsidiary of THE MMR GROUP, INC.

308 WEST BASIN ROAD • P.O. BOX 903 • NEW CASTLE, DE 19720
(302) 328-0500 • FAX (302) 328-0417



TEST REPORT

CORRPRO COMPANIES, INC.
ATTENTION: WALTER YOUNG
1380 ENTERPRISE DRIVE
WEST CHESTER, PA 19380

DATE: September 30, 2009

P.O. NO.: WC 4062

LEHIGH NO: J-53-2
Sample 3

PAGE NO.: 1 of 1

MATERIAL: CARBON STEEL
SPECIFICATION: ASTM A283-03 (REAPPROVED 2007), GRADE D
SAMPLE DESIGNATION: (1) SAMPLE: DISC MARKED IC, JOB NO: 332862

CHEMICAL ANALYSIS (%)

Carbon	0.25	
Sulfur	0.019	
Manganese	0.91*	*Exceeds requirement but within product tolerance IAW ASTM A6/A6M-03b.
Phosphorus	0.021	
Silicon	0.05	
Copper	0.23	
Nickel	0.09	
Chromium	0.04	
Molybdenum	0.02	

MECHANICAL PROPERTIES (Per ASTM A370-07A)

Diameter (inches):	0.253
Area (square inches):	0.0503
Yield Point (ksi):	45 - 54
Tensile Strength (ksi):	77
Elongation (%) in 1":	29
Reduction of Area (%):	56

What is this diameter

Based on the above testing this sample meets the chemical and tensile requirements of ASTM A283-03 (Reapproved 2007), Grade D.

ROCKWELL HARDNESS (Per ASTM E18-05)

78 HRBW

Hardness result is for information only.

LTL Procedure: QA-CH-P-018 Rev 3 (OES)

Lehigh Testing Laboratories, Inc.

Kevin M. Sexton

Peter M. Engelgau

Kevin M. Sexton, Mech. Testing Tech.

Peter M. Engelgau, Principal Chemist

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Appendix F – Coupon Test Results



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(302) 328-0500 • FAX (302) 328-0417



TEST REPORT

CORRPRO COMPANIES, INC.
ATTENTION: WALTER YOUNG
1380 ENTERPRISE DRIVE
WEST CHESTER, PA 19380

DATE: September 30, 2009

P.O. NO.: WC 4062

LEHIGH NO: J-53-2
Sample 2

PAGE NO.: 1 of 1

MATERIAL: CARBON STEEL
SPECIFICATION: ASTM A283-03 (REAPPROVED 2007), GRADE B
SAMPLE DESIGNATION: (1) SAMPLE: DISC MARKED 1D, JOB NO: 332862

CHEMICAL ANALYSIS (%)

Carbon	0.13
Sulfur	0.016
Manganese	0.40
Phosphorus	0.011
Silicon	0.06
Copper	0.01
Nickel	0.01
Chromium	0.03
Molybdenum	<0.01

MECHANICAL PROPERTIES (Per ASTM A370-07A)

Diameter (inches):	0.250
Area (square inches):	0.0491
Yield Point (ksi):	37
Tensile Strength (ksi):	59
Elongation (%) in 1":	36
Reduction of Area (%):	62

Based on the above testing this sample meets the chemical and tensile requirements of ASTM A283-03 (Reapproved 2007), Grade B.

ROCKWELL HARDNESS (Per ASTM E18-05)

68 HRBW

Hardness result is for information only.

LTL Procedure: QA-CH-P-018 Rev 3 (OES)

Lehigh Testing Laboratories, Inc.

Kevin M. Sexton

Peter M. Engelgau

Kevin M. Sexton, Mech. Testing Tech.

Peter M. Engelgau, Principal Chemist

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TEST REPORT

CORRPRO COMPANIES, INC.
ATTENTION: WALTER YOUNG
1380 ENTERPRISE DRIVE
WEST CHESTER, PA 19380

DATE: September 30, 2009

P.O. NO.: WC 4062

LEHIGH NO: J-53-2
Sample 1

PAGE NO.: 1 of 1

MATERIAL: CARBON STEEL
SPECIFICATION: ASTM A283-03 (REAPPROVED 2007), GRADE D
SAMPLE DESIGNATION: (1) SAMPLE: DISC MARKED 3A, JOB NO: 332862

CHEMICAL ANALYSIS (%)

Carbon	0.23
Sulfur	0.011
Manganese	0.85
Phosphorus	0.032
Silicon	0.04
Copper	0.05
Nickel	0.05
Chromium	0.05
Molybdenum	<0.01

MECHANICAL PROPERTIES (Per ASTM A370-07A)

Diameter (inches):	0.253
Area (square inches):	0.0503
Yield Point (ksi):	40
Tensile Strength (ksi):	76
Elongation (%) in 1":	29
Reduction of Area (%):	58

Based on the above testing this sample meets the chemical and tensile requirements of ASTM A283-03 (Reapproved 2007), Grade D.

ROCKWELL HARDNESS (Per ASTM E18-05)

77 HRBW

Hardness result is for information only.

LTL Procedure: QA-CH-P-018 Rev 3 (OES)

Lehigh Testing Laboratories, Inc.

Kevin M. Sexton

Peter M. Engelgau

Kevin M. Sexton, Mech. Testing Tech.

Peter M. Engelgau, Principal Chemist

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Appendix F – Coupon Test Results



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TEST REPORT

CORRPRO COMPANIES, INC.
ATTENTION: WALTER YOUNG
1380 ENTERPRISE DRIVE
WEST CHESTER, PA 19380

DATE: September 30, 2009

P.O. NO.: WC 4062

LEHIGH NO: J-53-2
Sample 5

PAGE NO.: 1 of 1

MATERIAL: CARBON STEEL
SPECIFICATION: ASTM A283-03 (REAPPROVED 2007), GRADE C OR D
SAMPLE DESIGNATION: (1) SAMPLE: DISC MARKED 5A, JOB NO: 332862

CHEMICAL ANALYSIS (%)

Carbon	0.22
Sulfur	0.031
Manganese	0.76
Phosphorus	0.018
Silicon	0.03
Copper	0.23
Nickel	0.07
Chromium	0.03
Molybdenum	0.01

MECHANICAL PROPERTIES (Per ASTM A370-07A)

Diameter (inches):	0.247
Area (square inches):	0.0479
Yield Point (ksi):	37
Tensile Strength (ksi):	68
Elongation (%) in 1":	29
Reduction of Area (%):	47

Based on the above testing this sample meets the chemical and tensile requirements of ASTM A283-03 (Reapproved 2007), Grade C or D.

ROCKWELL HARDNESS (Per ASTM E18-05)

79 HRBW

Hardness result is for information only.

LTL Procedure: QA-CH-P-018 Rev 3 (OES)

Lehigh Testing Laboratories, Inc.

Kevin M. Sexton

Peter M. Engelgau

Kevin M. Sexton, Mech. Testing Tech.

Peter M. Engelgau, Principal Chemist

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(302) 328-0500 • FAX (302) 328-0417



TEST REPORT

CORRPRO COMPANIES, INC.
ATTENTION: WALTER YOUNG
1380 ENTERPRISE DRIVE
WEST CHESTER, PA 19380

DATE: September 30, 2009

P.O. NO.: WC 4062

LEHIGH NO: J-53-2
Sample 4

PAGE NO.: 1 of 1

MATERIAL: CARBON STEEL
SPECIFICATION: ASTM A283-03 (REAPPROVED 2007), GRADE B
SAMPLE DESIGNATION: (1) SAMPLE: DISC MARKED 5B, JOB NO: 332862

CHEMICAL ANALYSIS (%)

Carbon	0.10
Sulfur	0.010
Manganese	0.50
Phosphorus	0.003
Silicon	<0.01
Copper	0.05
Nickel	0.04
Chromium	0.02
Molybdenum	<0.01

MECHANICAL PROPERTIES (Per ASTM A370-07A)

Diameter (inches):	0.249
Area (square inches):	0.0487
Yield Point (ksi):	48
Tensile Strength (ksi):	59
Elongation (%) in 1":	35
Reduction of Area (%):	69

Based on the above testing this sample meets the chemical and tensile requirements of ASTM A283-03 (Reapproved 2007), Grade B.

ROCKWELL HARDNESS (Per ASTM E18-05)

63 HRBW

Hardness result is for information only.

LTL Procedure: QA-CH-P-018 Rev 3 (OES)

Lehigh Testing Laboratories, Inc.

Kevin M. Sexton

Peter M. Engelgau

Kevin M. Sexton, Mech. Testing Tech.

Peter M. Engelgau, Principal Chemist

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Appendix G

Ultrasonic Test Results



332 E. Farrel Rd. Suite D
Lafayette, LA 70508
Telephone: (800) 204-0862
Fax: (337) 988-0641

Date: 9-7-09
Customer: Corrpro
Description: UT Inspection

SUMMARY

SCOPE:

- Provide Ultrasonic testing to determine the wall loss using a DMS A Scan instrument on client specified sewer pipe at client specified locations.

BACKGROUND:

- Material type is ASTM A283 Grade B, information supplied by MWH Global.
- Calculations were based on ANSI B 31.3.
- Design and relief pressures were assumed to be the working pressure at peak flow, information supplied by MWH.
- Design temperature was assumed to be 100°F.
- Born date for the 54" Force Main was 1965, information supplied by MWH.
- Born date for the 72" Force Main was 1975, information supplied by MWH.
- Nominal thickness was supplied by MWH.

FINDINGS:

- **1A-1-66-NDT AT EBSTP LEVEE-** No rejectionable findings were noted.
- **1B-1-54-NDT AT EBSTP LEVEE -** No rejectionable findings were noted.
- **1C-1-66-COUPON AT EBSTP -** There are 59 TML points with a calculated wall loss of 15% or greater, the highest being 24% at 7A-4.
- **1D-1-54-NDT COUPON AT EBSTP LEVEE-** No rejectionable findings were noted.

Appendix G – Ultrasonic Test Results



332 E. Farrel Rd. Suite D
Lafayette, LA 70508
Telephone: (800) 204-0862
Fax: (337) 988-0641

Date: 9-7-09

Customer: Corrpro

Description: UT Inspection

- **3A-3-54 COUPON AT W. B. IND. CANAL-** No rejectionable findings were noted.
- **4A-4-72-NDT AT FLORIDA AVENUE CANAL CROSSING-** No rejectionable findings were noted.
- **4B-4-54-NDT AT FLORIDA AVENUE CANAL CROSSING-** No rejectionable findings were noted.
- **5A-5-72-COUPON AT CROSSING OF PEOPLES AVENUE CANAL-** No rejectionable findings were noted.
- **5B-5-60 COUPON AT CROSSING OF PEOPLES AVENUE CANAL-**
There areas of moderate to severe pitting, where readings were not taken due to the poor condition of the pipe.
- **6A-6-60-NDT AT YARD OF PUMP STATION D-**There are 12 TML points with a calculated wall loss of 17% or greater, the highest being 24% at 5B.2, 5B.5 and 5B.9.
- **7A1-7-48-NDT AT ST. BERNARD AVE.-** No rejectionable findings
- **7A2-7-48-NDT AT ST. BERNARD AVE.-** No rejectionable findings
- **8A-8-72-NDT AT FRENCHMEN ST-** No rejectionable findings

NOTE:

- NVI, LLC certifies that the thickness data in this report is accurate to within the limits of the equipment used during the inspection. The calculations in this report are for informational use only. Any fitness for service assessment is the responsibility of the client.
- Technicians =Lee Hulin and Nick LaGrange, ASNT II

Appendix H

Guided Wave Test Results

Teletest® Inspection Report

FBS, Inc.

3340 West College Avenue
State College, PA 16801
T: (814) 234-3437, F: (814)234-3457
www.fbsworldwide.com



Long-Range Guided Wave Inspection Report

Sewer Force Main Inspection, New Orleans

Final Report

Project:

New Orleans Sewer Force Main LRUT Inspection

Job Number:

CPMWH001

Document Reference:

Final Report

Date:

11/16/2009

For:

Corrpro/MWH

Appendix H – Guided Wave Test Results

Teletest® Inspection Report

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1. Introduction

a) Background

Teletest[®] is a long-range ultrasonic NDT technology developed for detecting metal loss in pipe-work. It is a pulse-echo system aimed at testing large volumes of material from a single test point. Its initial application was for detecting corrosion under insulation in petrochemical plant pipe-work, but it has found widespread use in other inspection situations where pipes or tubes are not accessible, for example where they are buried, encased in a sleeve or elevated above the ground.

Teletest[®] is primarily a screening tool. The aim of the inspection is to test long lengths of pipe rapidly with 100% coverage of the pipe wall and to identify areas of corrosion or erosion for further evaluation using other NDT techniques such as radiography or conventional ultrasonic inspection. The technique is equally sensitive to metal loss on both the outside and inside surfaces of the pipe.

The system is entirely computer controlled, data acquisition and display/analysis being performed using a personal computer.

b) Scope of Work

FBS, Inc. was contracted by the Corpro Companies and MWH to perform LRUT pipe inspection services on two sewer force main pipelines in New Orleans, LA. The two (2) pipes of interest were as follows:

- 66 in. Diameter Carbon Steel Sewer Force Main Pipeline
- 54 in. Diameter Carbon Steel Sewer Force Main Pipeline

The scope of work included the completion of traditional axisymmetric scans of the pipes at multiple frequencies using both longitudinal and torsional mode excitation. Both pipes were coated with a tar coating and encased in concrete which limited the achievable diagnostic length. Phased array focusing was not used in these scans as bends were encountered on both pipes in both directions within close proximity to the placement of the tool. Note, focusing currently cannot be used to enhance inspection results beyond bends. Of particular interest were areas where the pipes penetrated the levy wall and were buried in soil heading west towards the canal. The tool was placed on sections of pipe that had been cleaned of coatings/insulation where applicable and that had as uniform a wall thickness as possible. This report presents the results of this inspection.

c) Flaw classification

Indications identified on the A-scan plots are evaluated on the basis of a combination of:

- The signal amplitude,
- The directionality of the focused response.

In order to provide a means of identifying defects which are potentially significant in terms of the integrity of the pipe it is also necessary to examine how localised the response is in terms of the pipe circumference. This may be obtained from the focused tests and is plotted on a polar response chart.

Teletest[®] is a screening tool, so that the classification of a response with respect to Amplitude is given as Category 1, 2 or 3 with Category 3 being the highest. A Category 2 or 3 classification of an anomaly denotes that the amplitude of the response was such that the presence of a large flaw greater than 9% cross-sectional area (CSA) is likely. A category 1 classification denotes that a definite signal was observed and pipe wall loss for this classification is generally between 3-9% CSA.

The collection of focussing data from suspected defects is also an integral part of the test regime. The results from focused tests on each defect are analysed in terms of the directionality of the response. This is also classified in terms of 1, 2, or 3 with Category 3 being the most localised and hence likely to be the most severe.

Further information on this classification is given in the appendix.

Quantitative inspections such as Radiography or Conventional UT are recommended on all classifications of anomalies.

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

d) Executive Summary

FBS, Inc. is not liable for the use of any information contained herein. All results are reported on a best-effort basis with no guarantee of being 100% accurate.

The Teletest system was originally designed for the detection of corrosion under insulation (CUI) applications. Buried and wrapped lines can be considered an extension of this application, albeit with a much higher rate of attenuation. Many factors can affect the quality of the results obtained with this system. The pipe diameter, pipe coatings and/ or wrappings, the ground conditions at the time of testing and the pipe contents will all influence the amount of usable data collected (usually called the Test Length or Diagnostic Length) and the quality of the data collected. Pipe geometry and tool placement also have an effect on signal quality. Ideally the tool should be positioned away from strong reflectors like flanges, pipe supports, branches, and welds. Additionally the tool should be placed to allow enough distance in front and behind of the tool to allow correct formation of the guided wave. For the sewer fore mains examined here, custom transducer collars were fabricated to deal with the large 54" and 66" diameter pipes. Standard collar sizes for the Teletest[®] system are only available for pipe sizes up to 48" in diameter. A summary of the sewer main pipes examined in New Orleans is as follows:

Pipe ID	Diameter	Datum Description	Comments	Photograph
66" Sewer Force Main	66in	Levy wall penetration 2 ft. 4 in. behind tool	<p>A reasonable signal to noise ratio was obtained in the backwards directions heading west towards the canal. Several weld-like indications were identified and should be confirmed. Two Category 1 indications were noted in the backwards direction.</p> <p>The signal quality was reduced in the forwards direction as the tool was placed directly against a steel band. Therefore, the inspection confidence is decreased. Several weld-like indications were identified in this direction and should be confirmed.</p>	
54" Sewer Force Main	54in	Levy wall penetration 5 ft. behind tool	<p>The signal to noise ratio obtained on this pipe was not as good as that obtained on the 66" pipe. Only half of the possible transducer modules were used due to complications with the electronics driving hardware which most-likely caused a loss of penetration power and the decreased signal to noise ratio. In addition, a pipe branch was within the near-field of the tool in the backwards direction which may have caused some distortion of the wave front. Several weld-like indications were identified in the backwards direction towards the canal and should be confirmed. Two Category 1 indications were also noted in the backwards direction. The quality of the scan in the forwards direction was again not as good as the tool was placed directly against the tar coating. A weld-like indication was noted in the forwards direction and should be confirmed.</p>	

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

2. Results

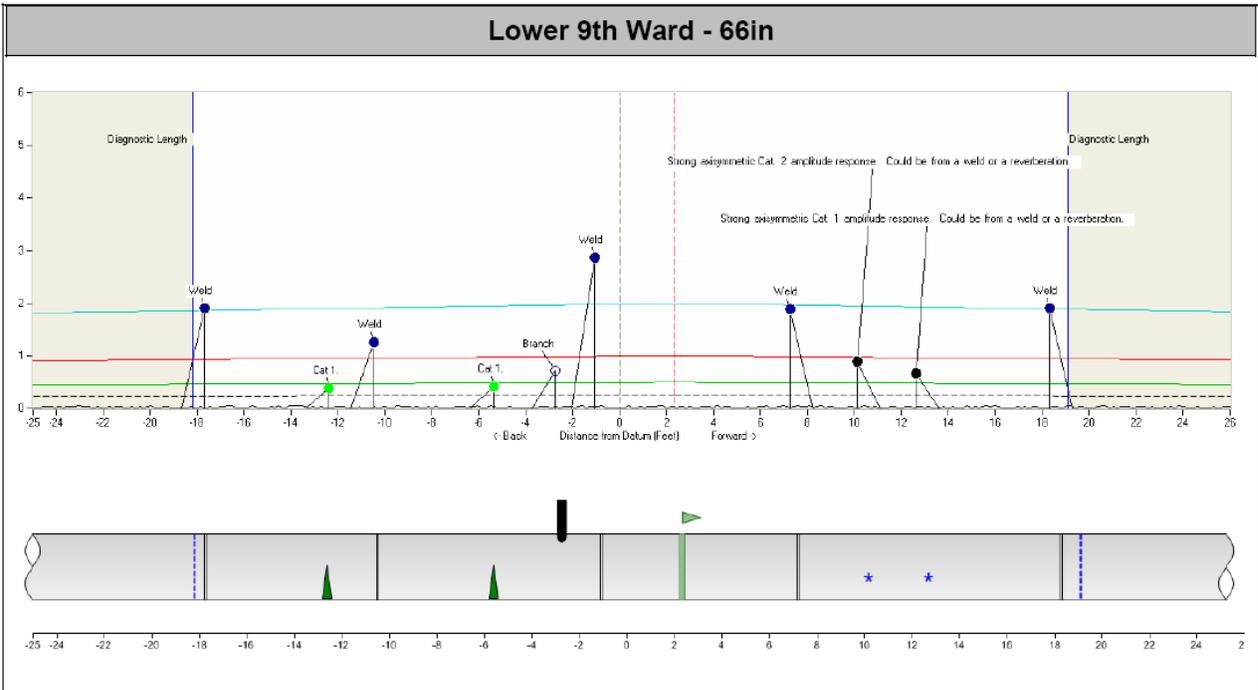
a) 66" Sewer Force Main

Pipe ID	Diameter	Datum Description	Comments
66" Sewer Force Main	66in	Levy wall penetration 2 ft. 4 in. behind tool	Several weld-like indications were noted and should be confirmed. Several Category 1 indications were also noted.

Datum is face of wall penetration 2 ft. 4" behind tool



Client	Corpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Direction	Both
Tool location	Lower 9th Ward	Test Operator	Jason Van Velsor
Pipe Ident.	66in Sewer Force Main	Collection Date	10/9/2009 12:23 PM
Nominal Dia.		Tool Type	Series 3 multi-mode modules, 30mm L
Wall Thickness	0.375in	Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Procedure			



Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

Distance relative to Datum	Indication Description	Comments
-17.7 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.
-12.4 ft	Cat 1.	
-10.5 ft	Weld	Unable to confirm via supplied drawings. Should be verified.
-5.4 ft	Cat 1.	
-2.8 ft	Branch	
-1.1 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.
7.2 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.
10.1 ft	See info	Strong axisymmetric Cat. 2 amplitude response. Could be from a weld. This indication could also be from a reverberating signal caused by the steel band in front of the tool.
12.6 ft	See info	Strong axisymmetric Cat. 1 amplitude response. Could be from a weld. This indication could also be from a reverberating signal caused by the steel band in front of the tool.
18.3 ft	Weld	Unable to confirm via supplied drawings. Should be verified.

Comments:

A reasonable signal to noise ratio was obtained in the backwards directions heading west towards the canal. Several weld-like indications were identified and should be confirmed. Two Category 1 indications were noted in the backwards direction.

The signal quality was reduced in the forwards direction as the tool was placed directly against a steel band. Therefore, the inspection confidence is decreased. Several weld-like indications were identified in this direction and should be confirmed. Also noted were Category 1 and 2 amplitude responses which were axisymmetric in nature implying they may be from welds or some other axisymmetric reflector (i.e., an axisymmetric coating disbond). These indications may also have been caused by some of the energy reverberating in the steel band directly in front of the tool.

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

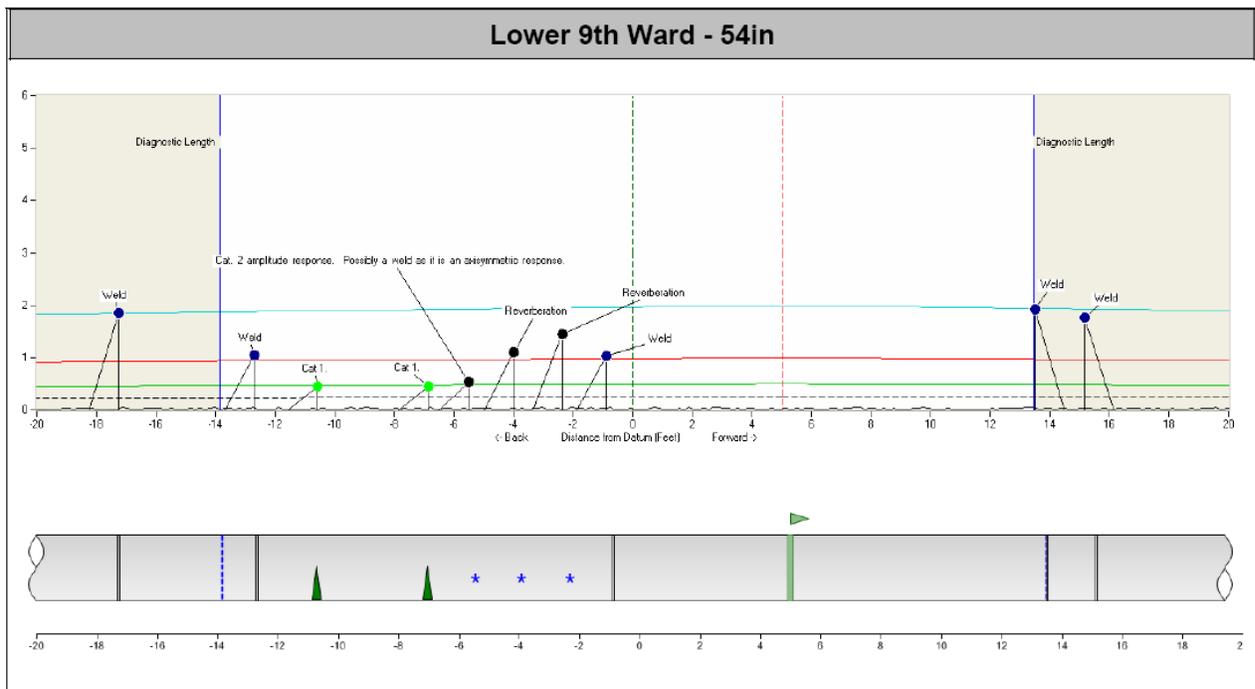
b) 54" Sewer Force Main

Pipe ID	Diameter	Datum Description	Comments
54" Sewer Force Main	54in	Levy wall penetration 5ft behind tool	Several weld-like indications were noted and should be confirmed. Several Category 1 indications were also noted.

Datum is face of wall penetration 5 behind tool



Client	TechCorr	Datum Point	Levy penetration
Site Location	Canal Crossing	Test Direction	Both
Tool location	Lower 9th Ward	Test Operator	Jason Van Velsor
Pipe Ident.	54in	Collection Date	10/8/2009 6:14 PM
Nominal Dia.		Tool Type	Series 3 multi-mode modules, 30mm L
Wall Thickness	0.500in	Diagnostic Length	-13.8ft to 13.5ft relative to the datum
Procedure			



Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

Distance relative to Datum	Indication Description	Comments	Priority
-17.3 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.	
-12.7 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.	
-10.6 ft	Cat 1.		Low
-6.9 ft	Cat 1.		Low
-5.5 ft	See info	Cat. 2 amplitude response. Possibly a weld as it is an axisymmetric response.	
-4.0 ft	See info	Reverberation	
-2.4 ft	See info	Reverberation	
-0.9 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified.	
13.5 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified. High flexural content noted.	
15.2 ft	Weld	Unable to confirm via supplied drawings or visually. Should be verified. High flexural content noted	

Comments:

The signal to noise ratio obtained on this pipe was not as good as that obtained on the 66" pipe. Only half of the possible transducer modules were used due to complications with the electronics driving hardware which most-likely caused a loss of penetration power and the decreased signal to noise ratio. Several weld-like indications were identified in the backwards direction towards the canal and should be confirmed. Two Category 1 indications were also noted in the backwards direction. The quality of the scan in the forwards direction was very poor as the tool was placed directly against the tar coating. Two weld-like indications were noted in the forwards direction and should be confirmed. The quality of the scan in this direction was so poor that there is very low confidence that flaw indications less than 20% of the pipe's cross sectional area could even be detected.

Appendix H – Guided Wave Test Results

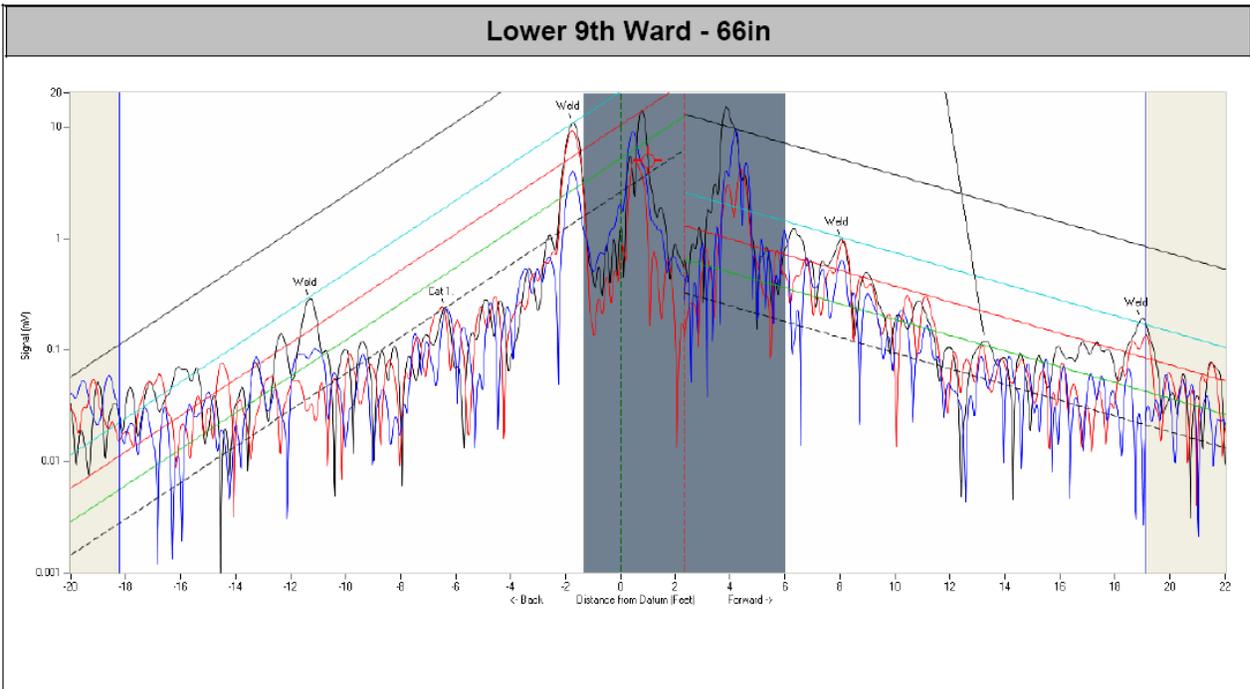
Teletest[®] Inspection Report

Appendix A: Detailed Results

a) 66" Sewer Force Main - 66in

This report contains the findings of a Teletest[®] inspection on the following:

Client	Corrpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	66in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	61 kHz
Wall Thickness	0.375in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Collection Date	10/9/2009 12:23 PM		



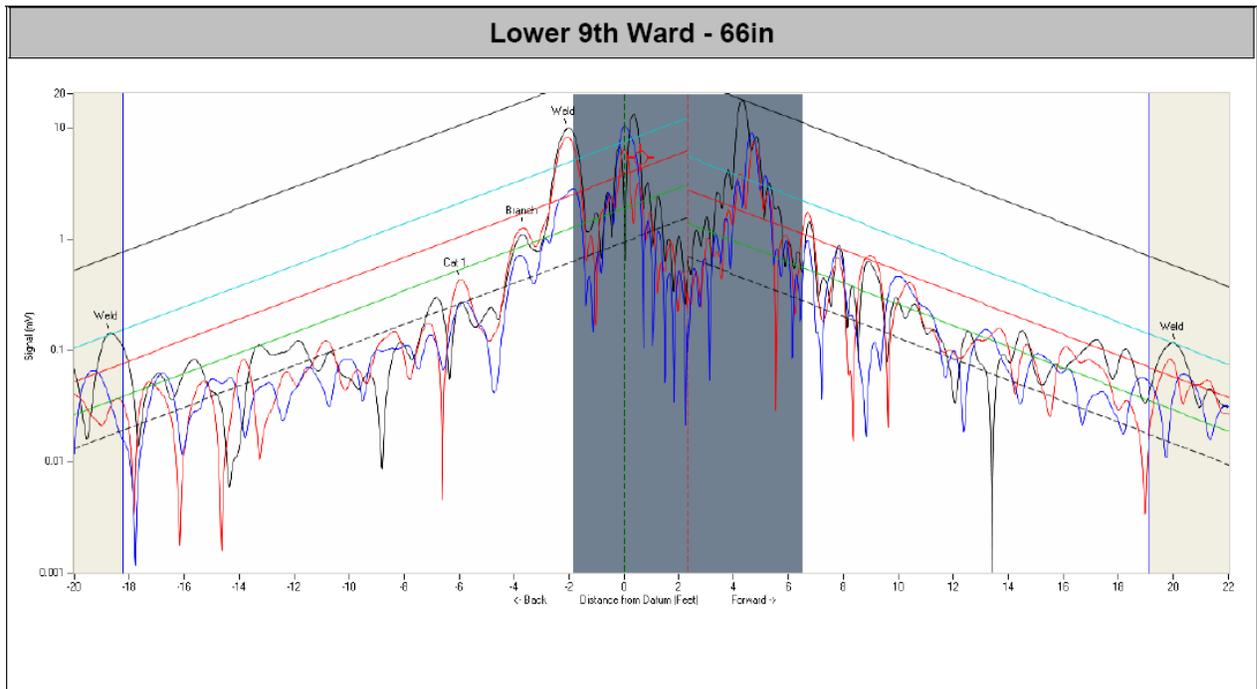
Distance relative to datum	Indication Description	Comments	Priority
-10.61ft	Weld		
-5.70ft	Cat 1.		Low
-1.03ft	Weld		
7.29ft	Weld		
12.52ft	See info	Strong axisymmetric Cat. 1 amplitude response. Could be from a weld or a reverberation.	
18.20ft	Weld		

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	Corpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	66in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	46 kHz
Wall Thickness	0.375in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Collection Date	10/9/2009 12:24 PM		



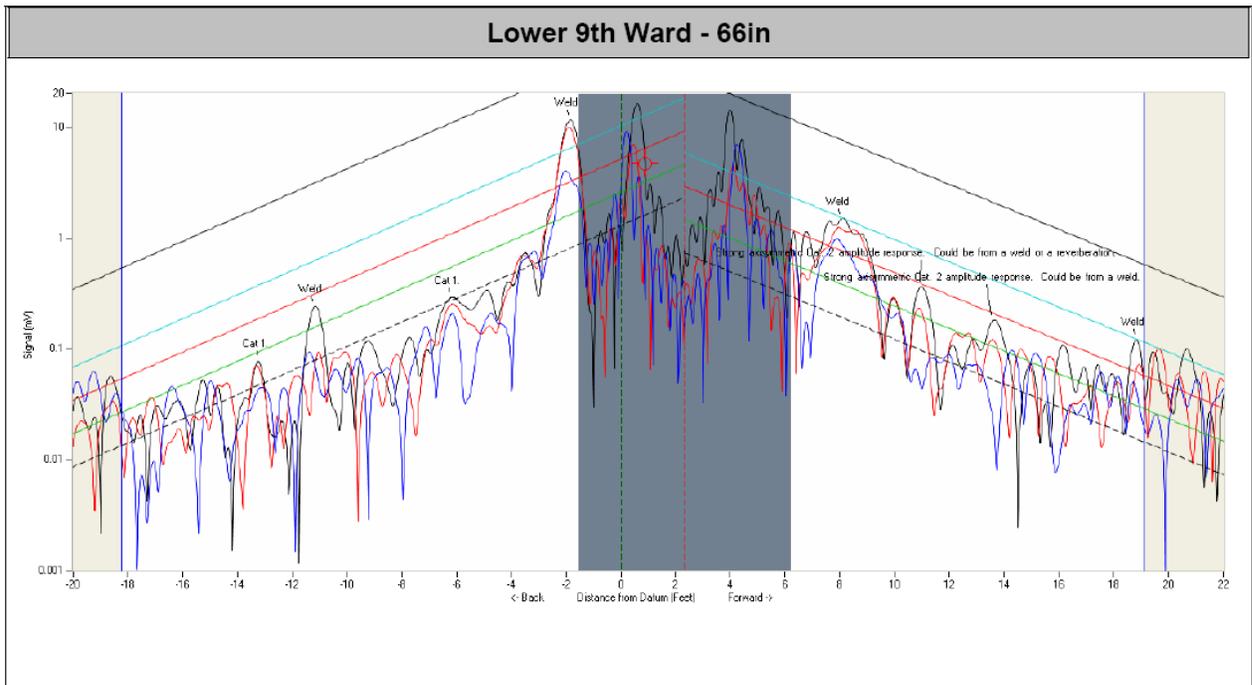
Distance relative to datum	Indication Description	Comments	Priority
-17.72ft	Weld		
-5.02ft	Cat 1.		Low
-2.75ft	Branch		
-1.08ft	Weld		
19.13ft	Weld		

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	Corpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	66in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	54 kHz
Wall Thickness	0.375in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Collection Date	10/9/2009 12:24 PM		



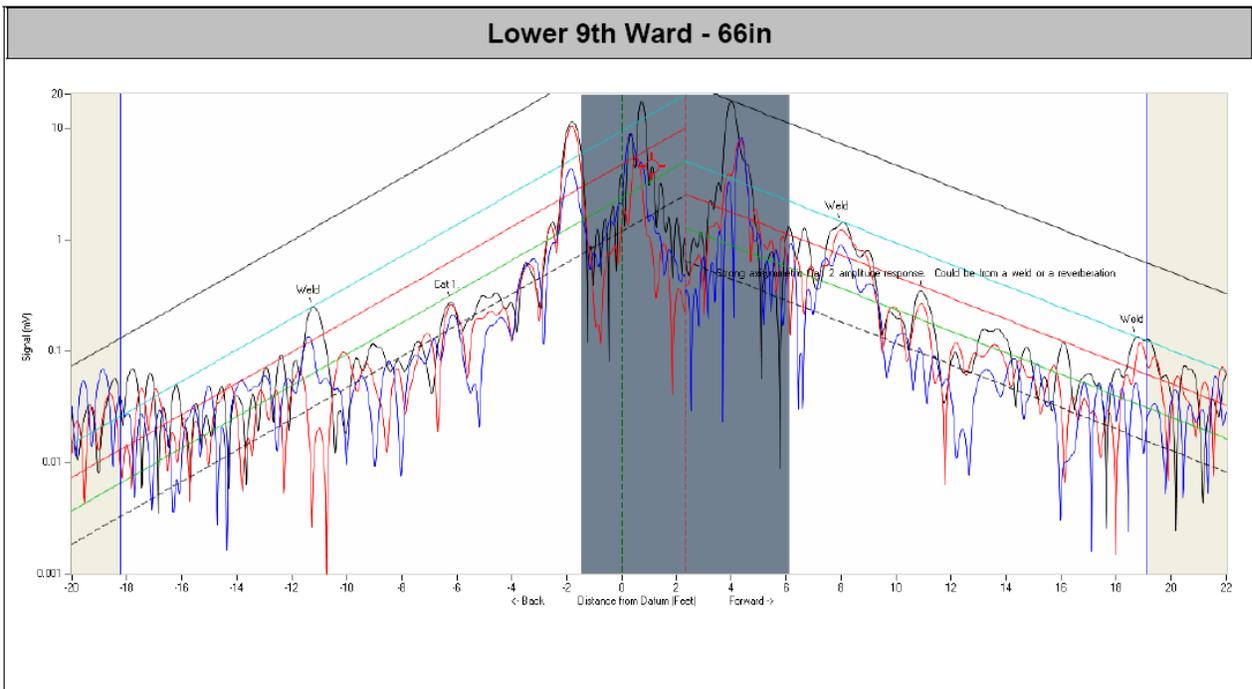
Distance relative to datum	Indication Description	Comments	Priority
-12.41ft	Cat 1.		Low
-10.35ft	Weld		
-5.41ft	Cat 1.		Low
-1.04ft	Weld		
7.24ft	Weld		
10.11ft	See info	Strong axisymmetric Cat. 2 amplitude response. Could be from a weld or a reverberation.	
12.74ft	See info	Strong axisymmetric Cat. 2 amplitude response. Could be from a weld.	
18.00ft	Weld		

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	Corpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	66in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	57 kHz
Wall Thickness	0.375in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Collection Date	10/9/2009 12:28 PM		



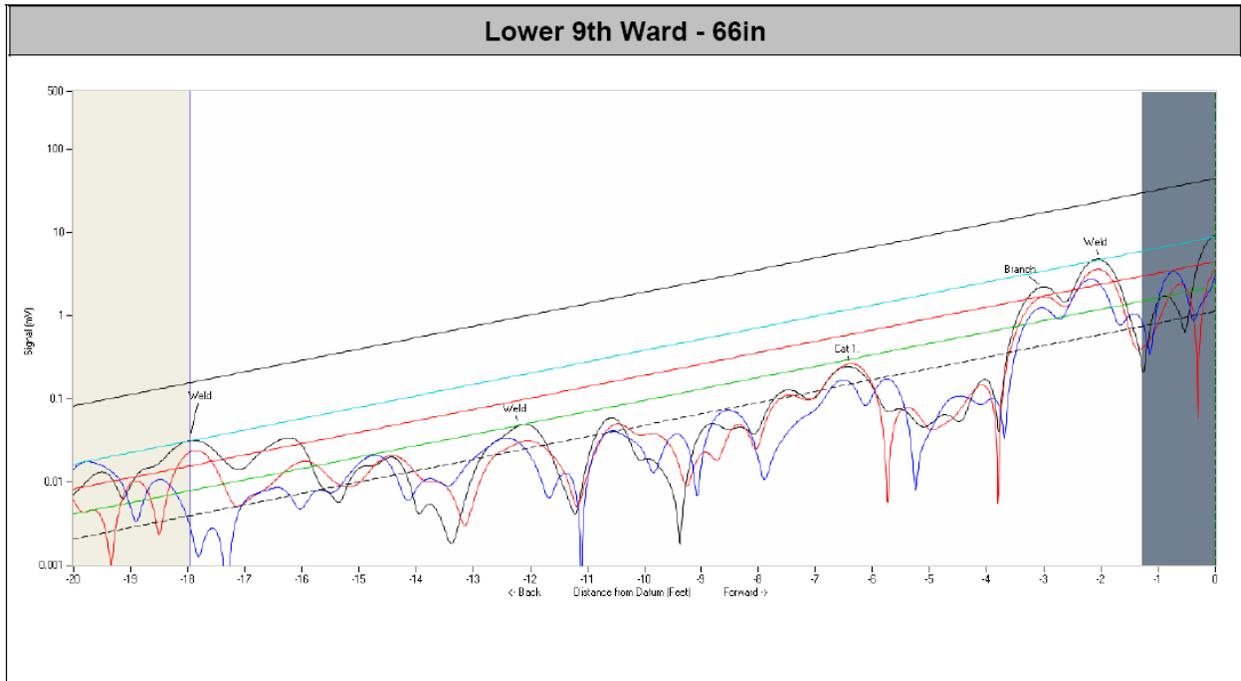
Distance relative to datum	Indication Description	Comments	Priority
-10.47ft	Weld		
-5.46ft	Cat 1.		Low
7.19ft	Weld		
10.09ft	See info	Strong axisymmetric Cat. 2 amplitude response. Could be from a weld or a reverberation.	
17.94ft	Weld		

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	Corpro	Datum Point	2ft 4in in front of levy penetration
Site Location	Canal Crossing	Test Wavemode	Torsional
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	66in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	27 kHz
Wall Thickness	0.375in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-18 ft to 18.5 ft relative to the datum
Collection Date	10/9/2009 11:57 AM		



Distance relative to datum	Indication Description	Comments	Priority
-16.98ft	Weld		
-11.21ft	Weld		
-5.42ft	Cat 1.		Low
-2.02ft	Branch		
-1.02ft	Weld		

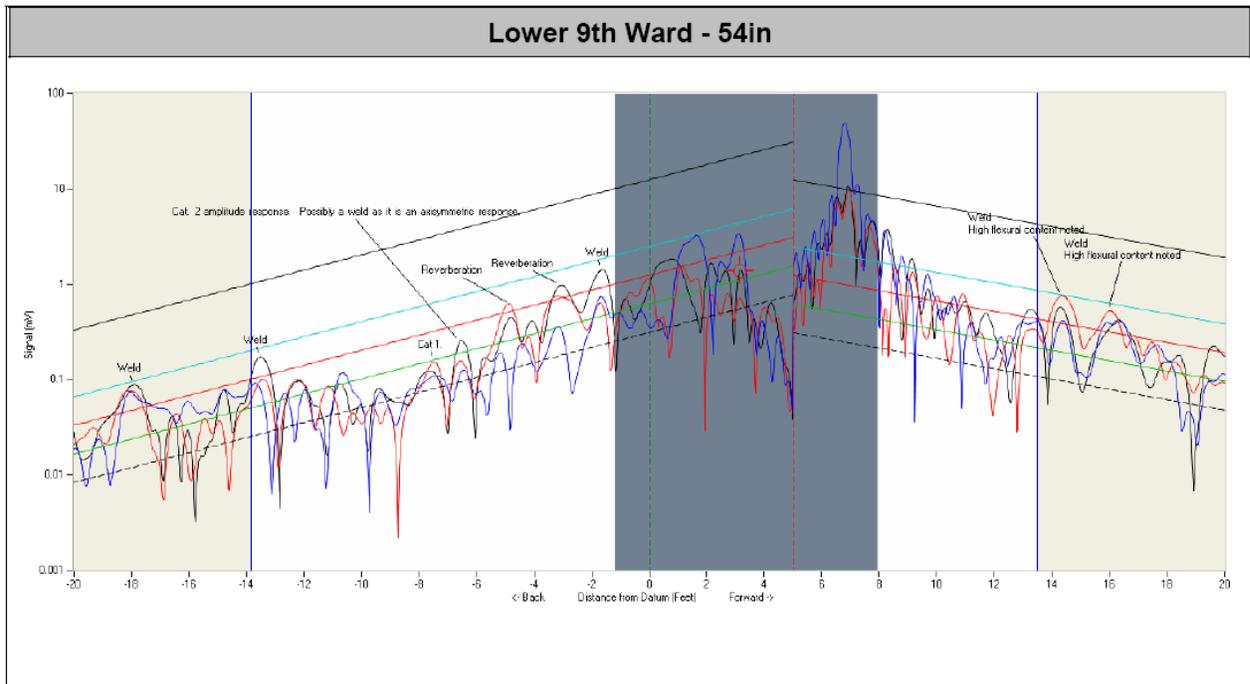
Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

b) 54" Sewer Force Main - 54in

This report contains the findings of a Teletest[®] inspection on the following:

Client	TechCorr	Datum Point	Levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	54in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	55 kHz
Wall Thickness	0.500in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-13.8ft to 13.5ft relative to datum
Collection Date	10/8/2009 6:14 PM		



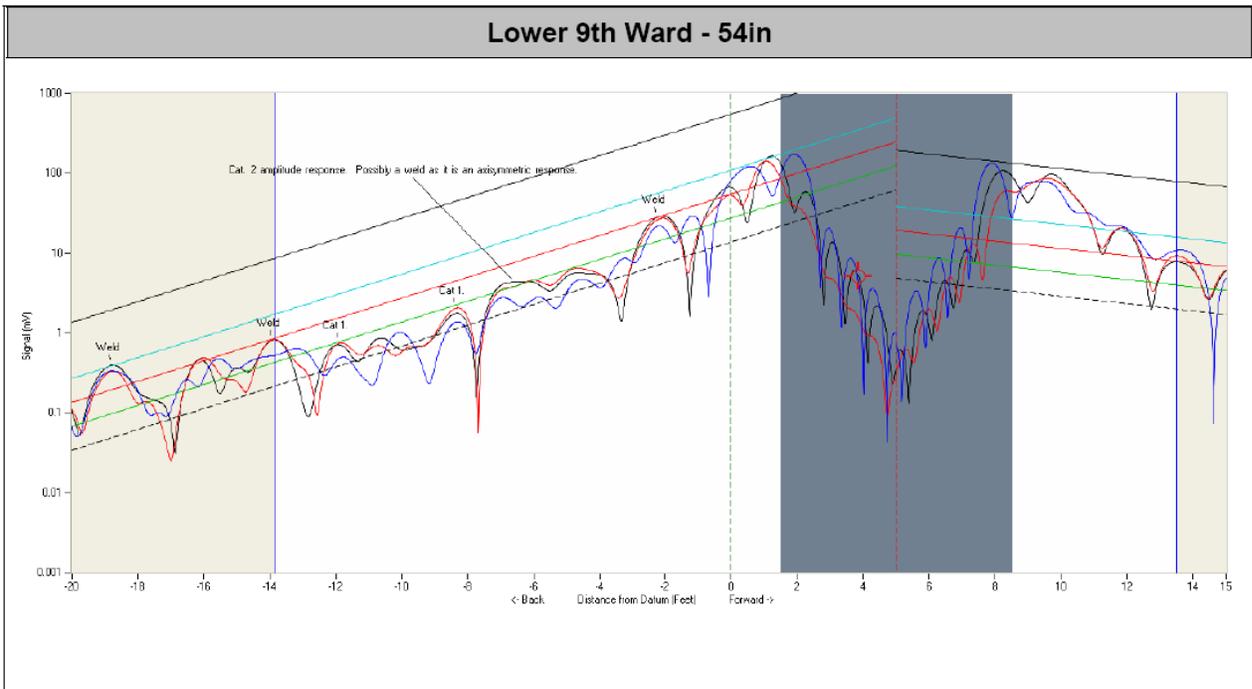
Distance relative to datum	Indication Description	Comments	Priority
-27.21ft	Weld		
-17.13ft	Weld		
-12.75ft	Weld		
-6.70ft	Cat 1.		Low
-5.77ft	See info	Cat. 2 amplitude response. Possibly a weld as it is an axisymmetric response.	
-4.00ft	See info	Reverberation	
-2.25ft	See info	Reverberation	
-0.86ft	Weld		
13.53ft	Weld	High flexural content noted	
15.13ft	Weld	High flexural content noted	

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	TechCorr	Datum Point	Levy penetration
Site Location	Canal Crossing	Test Wavemode	Torsional
Tool location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	54in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	20 kHz
Wall Thickness	0.500in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-13.8ft to 13.5ft relative to datum
Collection Date	10/8/2009 6:15 PM		



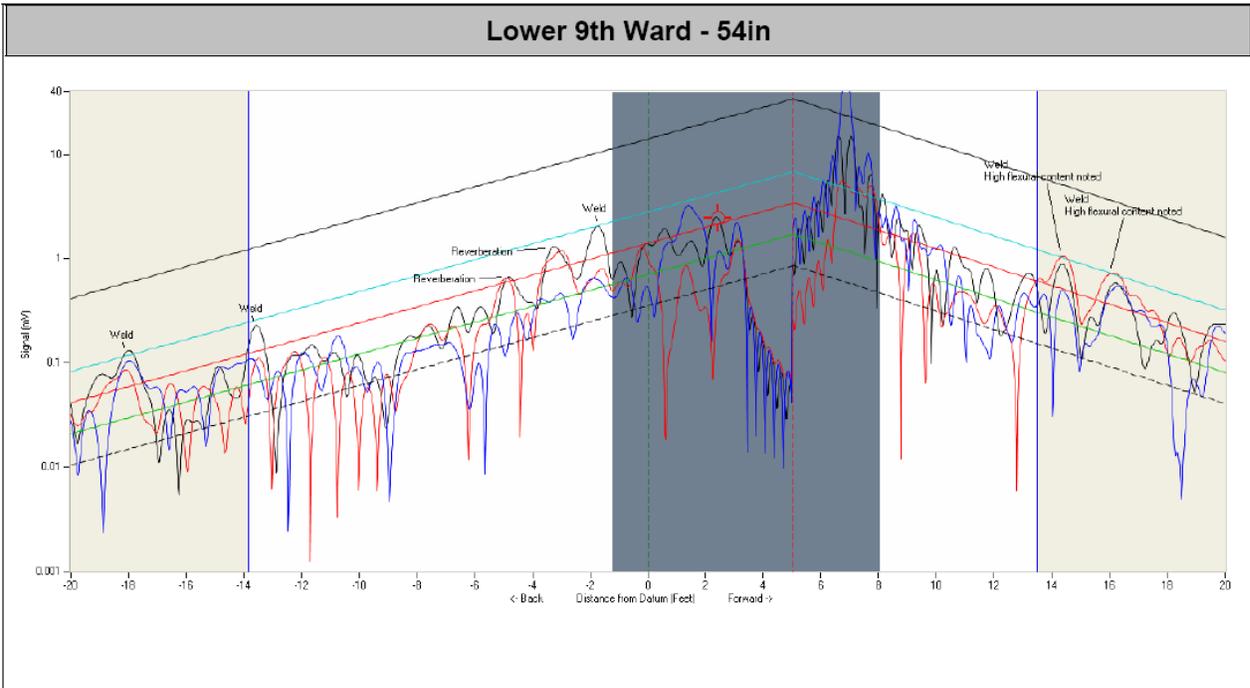
Distance relative to datum	Indication Description	Comments	Priority
-17.44ft	Weld		
-12.57ft	Weld		
-10.57ft	Cat 1.		Low
-7.04ft	Cat 1.		Low
-5.25ft	See info	Cat. 2 amplitude response. Possibly a weld as it is an axisymmetric response.	
-0.90ft	Weld		

Appendix H – Guided Wave Test Results

Teletest[®] Inspection Report

This report contains the findings of a Teletest[®] inspection on the following:

Client	TechCorr	Datum Point	Levy penetration
Site Location	Canal Crossing	Test Wavemode	Longitudinal
Tool Location	Lower 9th Ward	Test Direction	Both
Pipe Ident.	54in	Test Operator	Jason Van Velsor
Nominal Dia.		Test Frequency	53 kHz
Wall Thickness	0.500in	Tool Type	Series 3 multi-mode modules, 30mm L
Procedure		Diagnostic Length	-13.8ft to 13.5ft relative to datum
Collection Date	10/8/2009 6:24 PM		



Distance relative to datum	Indication Description	Comments	Priority
-17.25ft	Weld		
-12.78ft	Weld		
-4.00ft	See info	Reverberation	
-2.50ft	See info	Reverberation	
-0.87ft	Weld		
13.49ft	Weld	High flexural content noted	
15.20ft	Weld	High flexural content noted	

Appendix B:

a) PRINCIPLES OF OPERATION AND INTERPRETATION

i) BACKGROUND

Teletest[®] is a long-range ultrasonic non-destructive testing (NDT) technology developed for detecting metal loss in pipe-work. It is a pulse-echo system aimed at testing large volumes of material from a single test point. Its initial application was for detecting corrosion under insulation in petrochemical plant pipe-work, but it has found widespread use in other inspection situations where pipes or tubes are not accessible, for example where they are buried, encased in a sleeve or elevated above the ground.

Teletest[®] is primarily a screening tool. The aim of the inspection is to test long lengths of pipe rapidly with 100% coverage of the pipe wall and to identify areas of corrosion or erosion for further evaluation using other NDT techniques such as radiography or conventional ultrasonic inspection. The technique is equally sensitive to metal loss on both the outside and inside surfaces of the pipe.

The system is entirely computer controlled, data acquisition and display/analysis being performed using a personal computer. The equipment is shown in Fig.1.

ii) PRINCIPLES OF OPERATION

Teletest[®] employs low frequency guided waves, operating just above audible frequencies, propagated from a ring of transducers fixed around the pipe, Fig.1. These low frequencies (in ultrasonic terms) are necessary to enable the appropriate wave modes to be generated. At these frequencies a liquid couplant between the transducers and the surface is not necessary, satisfactory ultrasonic coupling being achieved with mechanical or pneumatic pressure applied to the back of the transducers to maintain contact with the pipe surface. The uniform spacing of the ultrasonic transducers around the pipe circumference allows guided waves to be generated that propagate symmetrically about the pipe axis. These may be visualized as a circular wave that sweeps along the pipe. The whole of the pipe wall thickness is excited by the wave motion, the pipe acting as a wave-guide - hence the term guided waves.

The propagation of these guided waves is governed principally by the frequency of the wave and the material thickness. Where the wave encounters a change in pipe wall thickness, whether an increase or a decrease, a proportion of the energy is reflected back to the transducers, thereby providing a mechanism for the detection of discontinuities. In the case of a pipe feature such as a girth weld, the increase in thickness is symmetrical around the pipe, so that the advancing circular wave front is reflected uniformly. Thus the reflected wave is also symmetrical, consisting predominantly of the same wave mode as the incident wave. In the case of an area of corrosion, the decrease in thickness will be localized, leading to scattering of the incident wave in addition to reflection and mode conversion will occur. The reflected wave will therefore consist of the incident wave mode plus the mode converted components. The mode-converted waves tend to cause the pipe to flex as they arise from a non-uniform source. The presence of these signals is a strong indicator of discontinuities such as corrosion. *Teletest*[®] is able to detect and to distinguish between symmetrical and flexural waves and both types are displayed.

The reflections are displayed as rectified signals in amplitude Vs distance 'A-scan' display, similar to that used in conventional ultrasonic inspections, but with a time-base range measured in tens of metres rather than centimetres.

A major complication for guided wave systems as distinct from conventional ultrasonic inspections is the dispersive nature of guided waves; that is to say, the velocity of most guided waves varies with their frequency. This causes a variety of complications, one being that to calibrate the time base of the A-scan to read distance and not time, requires a computer program to read in a velocity for the selected test frequency from a calibration, or 'dispersion' curve. There is a library of dispersion curves built into the *Teletest*[®] software for a range of pipe diameter/wall-thickness combinations.

Girth welds in the pipe produce dominant signals in the A-scan and act as important markers, used to set a distance amplitude correction (DAC) curve on the display with which signals from anomalies can be compared - see below.



Figure 1: Multi-Mode' Teletest® Equipment

iii) Evaluation method

Indications identified on the A-scan plots are evaluated on the basis of a combination of:

- The signal amplitude,
- The directionality of the focused response.

This takes into account that large amplitude responses will be from a large cross-sectional area defect. Small defects cannot produce large amplitude reflections. However, the converse is not always true; A small amplitude response does not necessarily mean that the defect is small, as the response may be affected by a number of factors.

In order to provide a means of identifying defects which are potentially significant in terms of the integrity of the pipe it is also necessary to examine how localized the response is in terms of the pipe circumference. This may be obtained from the focused tests and is plotted on a polar response chart.

To incorporate these changes, some aspects of the interpretation procedure have been altered compared with earlier versions of the *Teletest*® test procedures:

- Whereas the indications were previously assessed primarily in terms of amplitude, with the categories being 'Minor', 'Moderate' and 'Severe', the signals are now described as being of Amplitude Category 1, 2 or 3, with Category 3 being the highest.
- An additional DAC curve has been added to the analysis screen. This is a red line at -20dB compared with a 100% reflector (equivalent to a pipe end), so that it plots in between the blue weld line (-14dB) and the green 9% reflector line (-26dB). This defines the boundary between Categories 2 and 3 - see below.
- The additional DAC curve and the areas corresponding to the categories above are shown in Figure 2, below.
- Category 1 responses are those which are lower than the green -26dB line (formerly Minor).
- Category 2 responses are those above the -26dB line, but are lower than the new red line at -20dB (formerly Moderate)
- Category 3 responses exceed the new red -20dB line (these are broadly the same as the previous Severe classification, but the limiting amplitude is now better defined)
- **NOTE** - In practice, there is no lower cut off amplitude for the consideration of responses in these tests. Any signal which is recognisable above the baseline scatter level must be evaluated by the interpreter such that a decision is made regarding recommended follow up.

Appendix H – Guided Wave Test Results

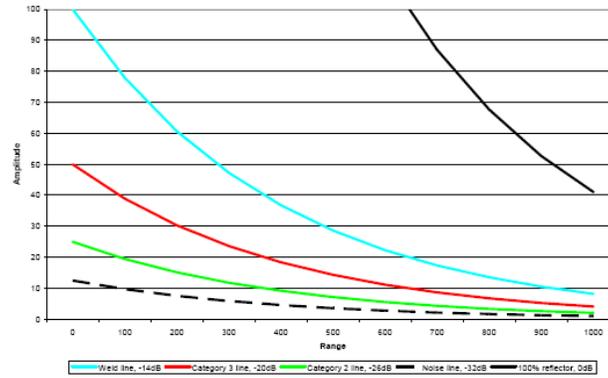


Figure 2. Schematic of the Teletest A-scan, showing the amplitude categories. Below the Green line is category 1, between the green and red line is category 2 and above the red is category 3

- The collection of focused data from suspected defects is an integral part of the test regime. The results from focused tests on each defect are analysed in terms of the directionality of the response.
- If the polar plot shows a high level of directionality, indicated by a single peak in the plot at one focus angle, it is classed as category 3 (figure 3). This indicates that the defect is highly localized on a narrow part of the circumference, so that it is likely to be deep for a given amplitude of response.

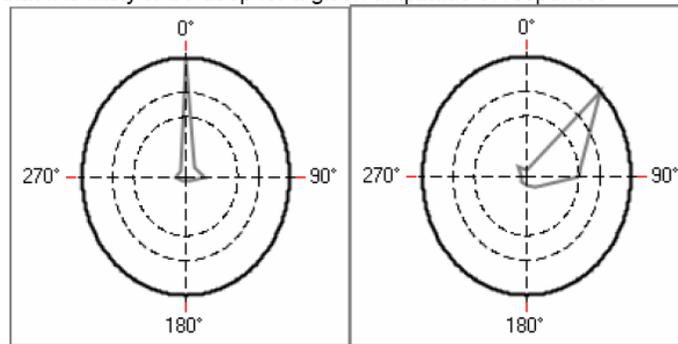


Figure 3. Category 3 responses from focused tests

- If the polar plot has two adjacent high amplitude responses it is classed as category 2. This is shown in figure 4. This suggests that the defect is localized, but has some circumferential length.

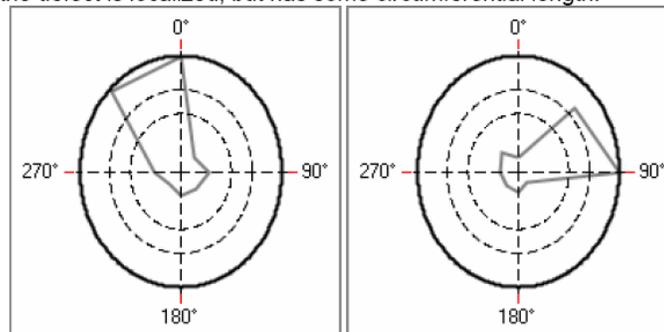


Figure 4. Category 2 responses from focused tests

- If the polar plot has 3 or more adjacent high amplitude peaks (figure 5) it is classed as category 1. This suggests that it is spread over a wide area of circumference, so that it is likely to be less deep for a given response amplitude.

Appendix H – Guided Wave Test Results

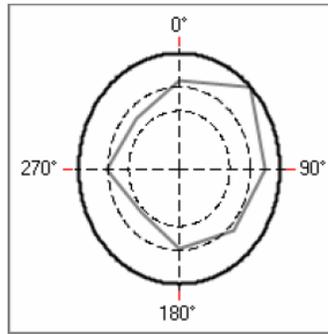


Figure 5. Category 1 response from a focused test

- Note, there is also a directionality category 0, which corresponds to the approximately uniform response around the circumference obtained from a weld, figure 6.

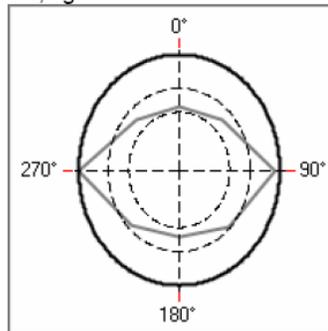


Figure 6. Category 0 response from a weld from a focused test

The overall classification is obtained by multiplying the two values, amplitude x directionality, obtained from a defect. A score of 3 or greater gives a recommendation for a High priority follow up, a score of 2 gives a Medium priority and a score of 1 gives a low priority. This is summarized in Table 1.

Amplitude	Directionality	Score	Follow up priority
3	3	9	High
3	2	6	High
3	1	3	High
3	0	0	Weld
2	3	6	High
2	2	4	High
2	1	2	Medium
1	3	3	High
1	2	2	Medium
1	1	1	Low

Table 1 Evaluation matrix

Hence a defect with a high amplitude response always results in a high priority follow up (unless deemed to be a feature such as a weld), as does a low amplitude response which is highly directional.

Quantitative inspections such as Radiography or Conventional UT are recommended on all classifications of anomalies.

Interpretation of the *Teletest*[®] signals requires thorough understandings of the factors that influence the test output and, as with any other sophisticated examination method, experience of the interpretation process. Plant Integrity Ltd provides training in both the operation of the system and the interpretation of results.

Plant Integrity Limited

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**GENERIC LONG RANGE ULTRASONIC
INSPECTION PROCEDURE**

**TELETEST[®]
DATA GATHERING AND INTERPRETATION**

Registered in England: No. 3341703 Registered Office: Granta Park, Great Abington, Cambridge CB1 6AL VAT No. 688 7236 75
Plant Integrity Limited is a wholly owned subsidiary of TWI (The Welding Institute).

Teletest Focus Procedure: Data gathering and interpretation

1. SCOPE

Teletest[®] is a means of rapidly surveying pipes for corrosion and other degradation using ultrasonic guided waves. This procedure gives the method for equipment set up, data collection and data interpretation for the *Teletest*[®] technique.

More details of the equipment and software are given in the *Teletest*[®] 'Guide to System Operation' and the '*Teletest*[®] User's Manual', which are supplied with the software.

2. EQUIPMENT

2.1. TEST EQUIPMENT

Laptop personal computer (PC) loaded with *Teletest*[®] software

Teletest[®] ultrasonic unit

Teletest[®] tools to fit pipes to be tested (transducers and mounting devices)

Umbilical lead

Interconnection leads

Ultrasonic thickness meter or flaw detector

Various tools

2.2. SOFTWARE

The laptop PC is supplied with *Teletest*[®] data acquisition and processing software. This software is subject to development and updates are issued periodically by Plant Integrity Ltd. Registered users are notified of such upgrades. The user should ensure that the latest version of the software is installed. Further information is available from Plant Integrity Ltd.

2.3. TRANSDUCER REQUIREMENTS

The *Teletest*[®] tool consists of five rings of piezoelectric transducers (three rings for the Minitest kit). A flexible modular arrangement is used. The tool size is chosen to fit the diameter of the pipe being tested. The number of transducers required in each ring depends on pipe diameter. Details are given in Table 1. For both types of tool, the individual transducer elements are connected in octants (quadrants for Minitest), each containing an equal number of elements.

3. TESTING PERSONNEL

As a minimum requirement, the *Teletest*[®] team leader shall have satisfactorily completed the Plant Integrity Ltd training course and shall have passed the end of course exam.

Teletest Focus Procedure: Data gathering and interpretation

4. SYSTEM SET UP

4.1. POWERING THE EQUIPMENT

A Li – Ion battery pack provides 24V DC power.
The battery pack is rated for greater than 25 locations inspection.

4.2. CONNECTING THE PC AND *TELETEST*[®] ULTRASONIC UNIT

The PC for the *Teletest*[®] unit are located remotely from the test site, normally in a cabin or vehicle.

The data link is provided via a PCMCIA or USB interface, which is inserted into an appropriate slot in the PC. This is connected to the umbilical by a socket on the power supply unit casing.

4.3. CONNECTING THE *TELETEST*[®] ULTRASONIC UNIT TO THE TRANSDUCER TOOL

The *Teletest*[®] ultrasonic unit is sited close to the transducer tool, the leads being kept short (~2m) to minimise any pick up of electrical noise. For the modular tools, the leads from the *Teletest*[®] unit terminate in eight 5-way connectors, coloured blue, red, orange and yellow, each of which is connected to the appropriate octant on the tool. The colour coding is displayed on the inflatable mounting collar.

4.4. ELECTRICAL TESTS

Transducer tool

It is essential to establish that the individual transducer elements within the tool are functioning correctly, so that the transducer as a whole behaves as expected. This is most easily achieved by measuring the capacitance of the transducer elements. Measurements of capacitance shall be made on the populated *Teletest*[®] tool prior to testing. The required capacitance may be calculated from the individual transducer capacitance and knowledge of the number of transducers in the tool. Expected values are given in Table 1.

It is also necessary to ensure that the tool does not present a low resistance load to the *Teletest*[®] unit, as this causes over-current faults. Using the transducer test box, measure the resistance of each quadrant for each ring on the tool using a multi-meter with a resistance range of at least 60 MOhms. The resistance of each quadrant should exceed 30 MOhms to avoid over-current errors. The errors are indicated on the diagnostics panel for *Teletest*[®] focus units. Note, the insulation resistance may also be subject to a more rigorous check in the workshop using a ‘Megger’ device at 250V.

Teletest Focus Procedure: Data gathering and interpretation

Cables

The transducer lead is tested for continuity and short circuits as part of the test regime for the transducer tool. The umbilical cables (2m and 50m) are prone to suffer damage through use and shall be checked before use using the umbilical tester box. There shall be continuity from pin to pin at each end, and no continuity between different pins. Continuity is indicated by illumination of the lights on the test box.

4.5. RUNNING THE TELETTEST® SOFTWARE

Launch the Teletest® software by double-clicking the icon on the PC screen. The program has two modes, 'Collection' and 'Analysis'. Select the 'Collection' mode to perform tests and to gather data. For the 'Analysis' function see Section 6.1 below. Detailed instructions for the operation of the software are given elsewhere (see Section 1).

5. PIPE TESTING

During data gathering (and for subsequent analysis) relevant information is required to be entered into the *Teletest*® program. It is recommended that this information is also recorded on a test sheet for reference.

(An example test sheet for recording test parameters is given in Appendix A)

5.1. DIMENSIONAL CHECKS

The diameter and wall thickness of the pipe to be tested shall be checked by means of suitable measuring equipment.

5.2. TELETTEST TOOL ATTACHMENT

5.2.1. Surface Preparation

The *Teletest*® transducers require direct contact with the pipe surface to couple the ultrasound into the pipe. No coupling fluid is necessary. The presence of thin, well-adhered coatings, such as paint, does not adversely affect the coupling.

The region where the tool is to be located shall be prepared with a wire brush and/or emery cloth to remove any loose corrosion products or poorly adhered paint. A surface condition is required, which is similar to that required for conventional ultrasonic testing.

5.2.2. Mounting of the Tool

It is important that the coupling of the ultrasound is as uniform around the pipe as possible. Care must therefore be taken that the device is centred on the pipe and that all the transducers come into adequate contact with the surface.

Teletest Focus Procedure: Data gathering and interpretation

5.2.3. Tool location

In the field the choice of suitable locations for the *Teletest*[®] tool may not be freely available in pipe systems. Wherever possible avoid locations equidistant between two consecutive girth welds, as this can cause superimposition of key features. Where possible the tool shall be positioned in the $\frac{1}{3}$, $\frac{2}{3}$ position between the welds. It is not advisable to position the tool closer than 1m from a weld or other feature, such as a branch or flange.

When mounting the tool the 'forward' test direction must be known and shall be recorded. The location of the tool (measured to the centre ring of transducers) relative to a known and agreed datum shall also be recorded. NB. The connectors on the tools face in the 'backward' test direction.

5.3. DATA GATHERING

5.3.1. Information to be recorded

The following information is required to be entered or set up prior to testing:

1. General information about the client, job no. pipe reference etc,
2. Pipe diameter (actual OD, mm), wall thickness (measured, mm) and the pipe schedule (if applicable).
3. The separation distance between adjacent rings in the transducer tool. This depends on the pipe size and test frequency.
4. The position of the transducer relative to the datum. The datum location may also be described.

5.3.2. Amplitude Normalisation

Normalisation of the transducer rings is carried out automatically by the software.

5.3.3. Data collection

Once the set up sequence, above, is completed the software will automatically collect the data. The software automatically calculates the optimum frequencies for the wavemodes used, pipe size and condition.

6. INTERPRETATION

6.1. POST PROCESSING

The raw data sets are processed to produce an A-scan display with an associated improvement in rejection of unwanted ultrasonic signals and the ability to display mode-converted responses. This may be done directly after data collection in the 'Collection' mode of the *Teletest*[®] program, or from previously stored data using the 'Analysis' option.

6.2. DETERMINATION OF REFERENCE LEVELS

The ultrasonic responses are assessed with respect to a number of calibration thresholds. These are:

Teletest Focus Procedure: Data gathering and interpretation

- 0dB equivalent to a pipe end, flange or 100% reflector
- -14dB equivalent to an idealised weld
- -26dB equivalent to an idealised 9% of pipe wall cross-sectional area
- -32dB The target noise level to achieve at least a 6dB signal to noise ratio from a 9% pipe wall cross-sectional area reflector.

These, combined with a measurement of the rate of attenuation of the ultrasound taken from the A-scan display, allow a set of DAC curves to be plotted, which are then fitted to the test data.

This provides the basis for assessment of the features on the processed output.

6.3. DETERMINATION OF VALID TEST RANGE

This is determined by the test length for which the background ultrasonic 'grass' level does not exceed the -32dB level, i.e. the range over which the signal-to-noise ratio is at least 6dB at the reporting level. The range from the transducer in the test direction over which the above signal to noise criterion is met, shall be determined and recorded. Beyond this range, the target sensitivity of detection of metal loss of 9% of the wall cross-section will not necessarily be achieved. Areas within the valid test length where interpretation is not practical (eg reverberations from welds) shall also be recorded. The longitudinal accuracy of the technique is approximately 100mm.

6.4. EVALUATION METHOD

Indications identified on the A-scan plots are evaluated on the basis of a combination of:

- The signal amplitude,
- The directionality of the focused response.

This takes into account that large amplitude responses will be from a large cross-sectional area defect. Small defects cannot produce large amplitude reflections. However, the converse is not always true; A small amplitude response does not necessarily mean that the defect is small, as the response may be affected by a number of factors.

In order to provide a means of identifying defects which are potentially significant in terms of the integrity of the pipe it is also necessary to examine how localised the response is in terms of the pipe circumference. This may be obtained from the focused tests and is plotted on a polar response chart.

To incorporate these changes, some aspects of the interpretation procedure have been altered compared with earlier versions of the *Teletest*[®] test procedures:

Whereas the indications were previously assessed primarily in terms of amplitude, with the categories being 'Minor', 'Moderate' and 'Severe', the signals are now described as being of Amplitude Category 1, 2 or 3, with Category 3 being the highest.

Teletest Focus Procedure: Data gathering and interpretation

An additional DAC curve has been added to the analysis screen. This is a red line at -20dB compared with a 100% reflector (equivalent to a pipe end), so that it plots in between the blue weld line (-14dB) and the green 9% reflector line (-26dB). This defines the boundary between Categories 2 and 3 - see below.

The additional DAC curve and the areas corresponding to the categories above are shown in Figure 1, below.

Category 1 responses are those which are lower than the green -26dB line (formerly Minor).

Category 2 responses are those above the -26dB line, but are lower than the new red line at -20dB (formerly Moderate)

Category 3 responses exceed the new red -20dB line (these are broadly the same as the previous Severe classification, but the limiting amplitude is now better defined)

NOTE - In practice, there is no lower cut off amplitude for the consideration of responses in these tests. Any signal which is recognisable above the baseline scatter level must be evaluated by the interpreter such that a decision is made regarding recommended follow up.

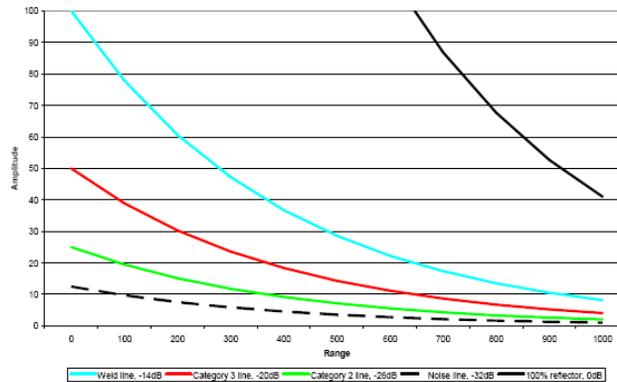


Figure 1. Schematic of the Teletest A-scan, showing the amplitude categories. Below the Green line is category 1, between the green and red line is category 2 and above the red is category 3

The collection of focused data from suspected defects is an integral part of the test regime. The results from focused tests on each defect are analysed in terms of the directionality of the response.

If the polar plot shows a high level of directionality, indicated by a single peak in the plot at one focus angle, it is classed as category 3 (figure 2). This

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indicates that the defect is highly localised on a narrow part of the circumference, so that it is likely to be deep for a given amplitude of response.

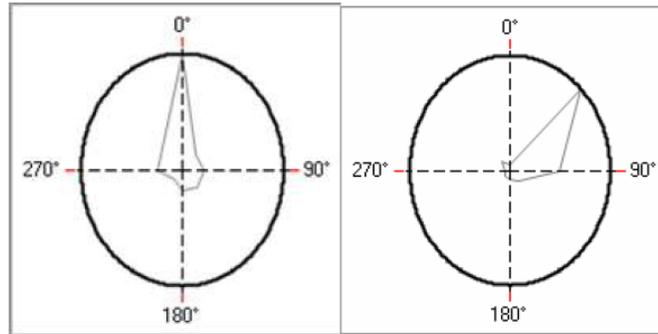


Figure 2. Category 3 responses from focused tests

If the polar plot has two adjacent high amplitude responses it is classed as category 2. This is shown in figure 3. This suggests that the defect is localised, but has some circumferential length.

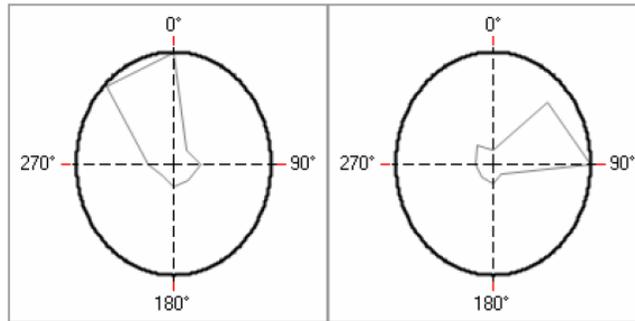


Figure 3. Category 2 responses from focused tests

If the polar plot has 3 or more adjacent high amplitude peaks (figure 4) it is classed as category 1. This suggests that it is spread over a wide area of circumference, so that it is likely to be less deep for a given response amplitude.

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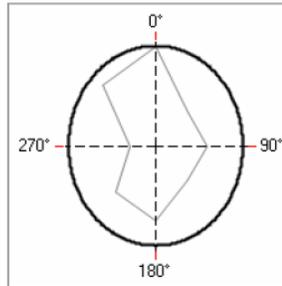


Figure 4. Category 1 response from a focused test

Note, there is also a directionality category 0, which corresponds to the approximately uniform response around the circumference obtained from a weld, figure 6.

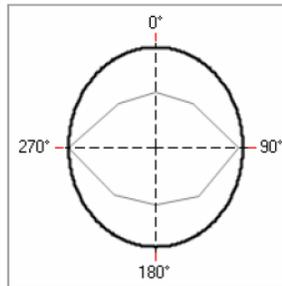


Figure 5. Category 0 response from a weld from a focused test

The overall classification is obtained by multiplying the two values, amplitude \times directionality, obtained from a defect. A score of 3 or greater gives a recommendation for a High priority follow up, a score of 2 gives a Medium priority and a score of 1 gives a low priority. This is summarised in Table 1.

Table 1 Evaluation matrix

Amplitude	Directionality	Score	Follow up priority
3	3	9	High
3	2	6	High
3	1	3	High
3	0	0	Weld
2	3	6	High
2	2	4	High
2	1	2	Medium
1	3	3	High
1	2	2	Medium
1	1	1	Low

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Hence a defect with a high amplitude response always results in a high priority follow up (unless deemed to be a feature such as a weld), as does a low amplitude response which is highly directional.

Quantitative inspections such as Radiography or Conventional UT are recommended on all classifications of anomalies.

Interpretation of the *Teletest*[®] signals requires thorough understandings of the factors that influence the test output and, as with any other sophisticated examination method, experience of the interpretation process. Plant Integrity Ltd provides training in both the operation of the system and the interpretation of results.

7. REPORTING

In all cases a report sheet shall be produced (from within the *Teletest*[®] software) which gives full details of the pipe tested and the findings. Where appropriate a print out of the A-scan trace shall be provided to support the decisions made about indications sentenced.

8. REFERENCES AND STANDARDS.

The Teletest Procedure is written with a full appreciation of the following standards.

- **API 570** Piping Inspection Code Inspection, Repair, Alteration, and Rerating of In-Service Piping Systems
- **API 579** Fitness for Service of Piping, Vessels & Tanks
- **B31.3 - 2002 - Process Piping**

Although Teletest Focus is a screening tool, the technique is a very useful tool for satisfying these important pipeline standards through effective follow-up and sizing of potential defects using complimentary techniques such as Corrosion Mapping, conventional UT or Radiography.

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Table 1. Transducer configurations for different pipe diameters.

Teletest Focus MK3 Collars					
Modules and Transducer Numbers Required for Different Pipe Sizes and Collar Combinations for Larger Pipes					
Pipe Size	Collar 1 Size	Collar 2 Size	No. of Modules	Transducers	Collar Rollers
2"	2" Mini-Module		8	24	
3"	3" Mini-Module		12	36	
4"	4" Mini-Module		16	48	
6"	6"		24	120	
8"	8"		24	120	
10"	10"		32	160	
12"	12"		32	160	
14"	14"		40	200	
16"	16"		40	200	
18"	18"		48	240	
20"	20"		48	240	
22"	22"		56	280	
24"	24"		56	280	
26"	10"	10"	60	300	4
28"	10"	12"	60	300	4
30"	12"	14"	68	340	4
32"	12"	16"	68	340	4
34"	14"	16"	76	380	4
36"	14"	18"	84	420	4
38"	16"	18"	84	420	4
40"	14"	22"	92	460	4
42"	18"	20"	92	460	4
44"					
46"	20" & 22" To Be Confirmed		100	500	4
48"	20"	24"	100	500	4

The average capacitance of *Teletest*[®] transducers is 859pF (0.859nF). The table provides a guide to the nominal value to be expected for each quadrant on *Teletest*[®] tools of different diameters.

In practice the measured values will be slightly higher than those quoted as the leads and interconnecting wiring have additional capacitance which adds to the total.