12-Inch Unit A Rancho Santa Fe Road Pipeline Inspection and Condition Assessment Report

Olivenhain Municipal Water District

Carlsbad, CA

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Executive Summary

Olivenhain Municipal Water District (District) selected HDR Engineering, Inc. (HDR) to guide and support the inspection and condition assessment of the 12-inch Unit A pipeline located along Rancho Santa Fe Road, and document recommendations for future defect remediation, inspection and opinions of cost. Electromagnetic Remote Field Testing (RFT) inspection of the 12-inch pipeline was performed by Pipeline Inspection and Condition Analysis Corporation (PICA) using the SeeSnake tool shown in Figure ES 1-1. Additionally, video inspection was accomplished for a portion of the pipeline. Inspection of the 12-inch pipeline was performed in January 2020.

The 1,401 feet of assessed 12-inch pipeline is located along Rancho Santa Fe Road between Las Olas Court and the intersection of Avenida La Posta and Calle Acervo. It is a cement mortar lined and coated (CML&C) steel pipeline constructed in 1961 as part of the project known as Unit A. Three additional locations along the 14,634 feet of Unit A pipeline were also considered for assessment. A strategic decision was made to perform assessment at one location and utilize the assessment results to make recommendations for the other portions of Unit A.

Table ES 1-1 presents additional information on the pipeline. Figure ES 1-2 presents the location of the pipeline and assessment extents along Rancho Santa Fe Road.

Figure ES 1-1. PICA SeeSnake

Table ES 1-1. Pipeline Inspection Information

Alignment Name	Unit A Pipe Length (ft)	Pipe Length Assessed (ft)	Assessed Diameter (in)	Material	Install Year	Cathodic Protection	Assessed Location
Unit A - Rancho Santa Fe Road	14,634	1,401	12	CML&C Steel	1961	Cathodic protection and test stations were installed after initial construction.	Rancho Santa Fe Road from Las Olas Court to Avenida La Posta and Calle Acervo.

Figure ES 1-2. 12-Inch Unit A Rancho Santa Fe Road Pipeline

Key conclusions from the work include the following:

- The District is implementing industry best practices through inspection and cathodic protection to proactively manage aging pipeline infrastructure.
- There are several areas on the assessed pipeline with significant wall loss that are recommended to be remediated over the next 3 to 5 years. There were no defects requiring urgent or emergency identified for the 12-inch pipe. Although there are locations identified by PICA with significant wall losses, failure of the 12-inch steel pipeline would likely be less consequential than failure of the 27-inch Unit K and 24-inch Unit B pipelines assessed previously. The assessed 12-inch pipeline can also be shut-down and bypassed without customer interruption. Moreover, the pipeline is located less than one quarter mile from the District operations yard, facilitating rapid response to breaks or leaks.
- Repair costs were evaluated against pipeline rehabilitation (lining) and replacement alternatives to identify a recommended approach. Because the estimated cost of repairs is high—at 49 to 84 percent of replacement costs—replacement is recommended. Rehabilitation through lining could result in some savings and should be evaluated during planning and design.
- The inspection findings identified defects likely caused by construction practices. Based on these findings, the portions of the original pipeline construction project that were not inspected are likely to have similar defects. Low-impact assessments are recommended to plan future rehabilitation or replacement of these portions of the pipeline.
- Several condition assessment methods were evaluated and the following low-impact methods are recommended for the remaining portions of the Unit A pipeline. These methods do not typically require excavation or pipeline shutdowns with dewatering.
    - Annual cathodic protection surveys – The District currently has a program in place.
    - Opportunistic condition assessment during valve replacement, service lateral installation or other opportunities where the pipeline is exposed
    - Corrosion survey to identify corrosive soil hot spots and potential areas of active corrosion
    - Leak detection survey – Consider lower cost leak detection methods that can be performed from the surface during assessment planning.

  Depending on the results of these assessments, excavations for spot repairs and external direct assessments may be appropriate.
- HDR recommends the District begin planning to replace or rehabilitate portions of Unit A in the near future. The exact timing of the work should be determined based on the perceived consequence a break might have on District operations.
- **The recommended near-term approach (within 3 to 5 years) is to replace or rehabilitate the assessed part of Unit A and perform low-impact assessment of the unassessed part of Unit A. The opinion of cost for replacement is $1.0 to**

1.7 million. The opinion of cost for low-impact assessment of the unassessed part of Unit A is $370,000.

- **The recommended long-term approach (5 to 10 years or more) is to prioritize and plan replacement or rehabilitation of the unassessed part of Unit A using the results of low-impact assessments. The opinion of cost for replacement is $7.7 to 13.5 million. The opinion of cost for rehabilitation is $5.0 to $8.8 million.**

Additional recommendations include:

- Perform regular cathodic protection surveys and confirm adequate cathodic protection is provided. Annual surveys are recommended.
- Plan for regular appurtenance and emergency pipeline repairs. Materials should be stockpiled and funding should be reserved for emergency repairs.
- Incorporate other high-risk pipelines into proactive condition assessment and monitoring plans.

Inspection findings have been organized by defect severity and grouped in order to prioritize defects. The defects identified include the following:

- There are no urgent or emergency Group 1 defects identified for immediate investigation or repair.
- There are 16 Group 2 defects including 13 identified using PICA data and 3 identified by video inspection. These defects are identified for near-term repair and investigation in the next 3 to 5 years. There are also two anomalies identified by PICA that are recommended for repair and investigation. The total number of Group 2 defects and anomalies is 18.
- There are 53 Group 3 defects including 26 identified using PICA data and 27 identified through video inspection. These defects are recommended for monitoring.

Example Group 2 video inspection defects are presented in Figure ES 1-3 and example Group 3 defects are presented in Figure ES 1-4.

Figure ES 1-3. Group 2 Video Inspection Defect Examples With Significant Bare Steel and Rust

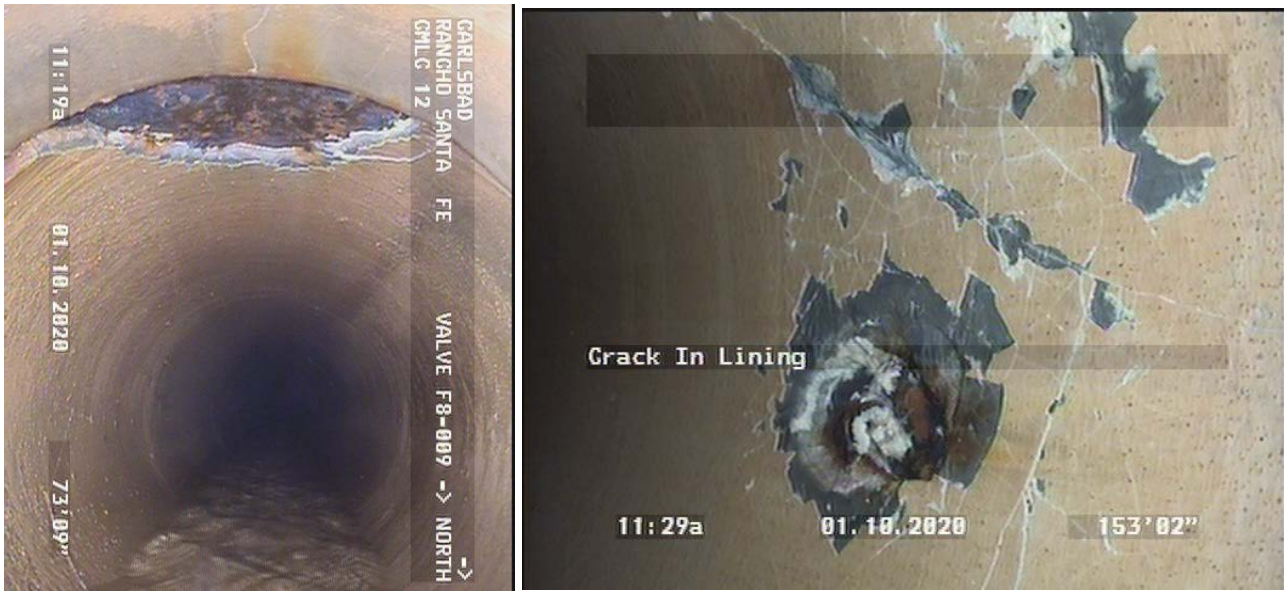
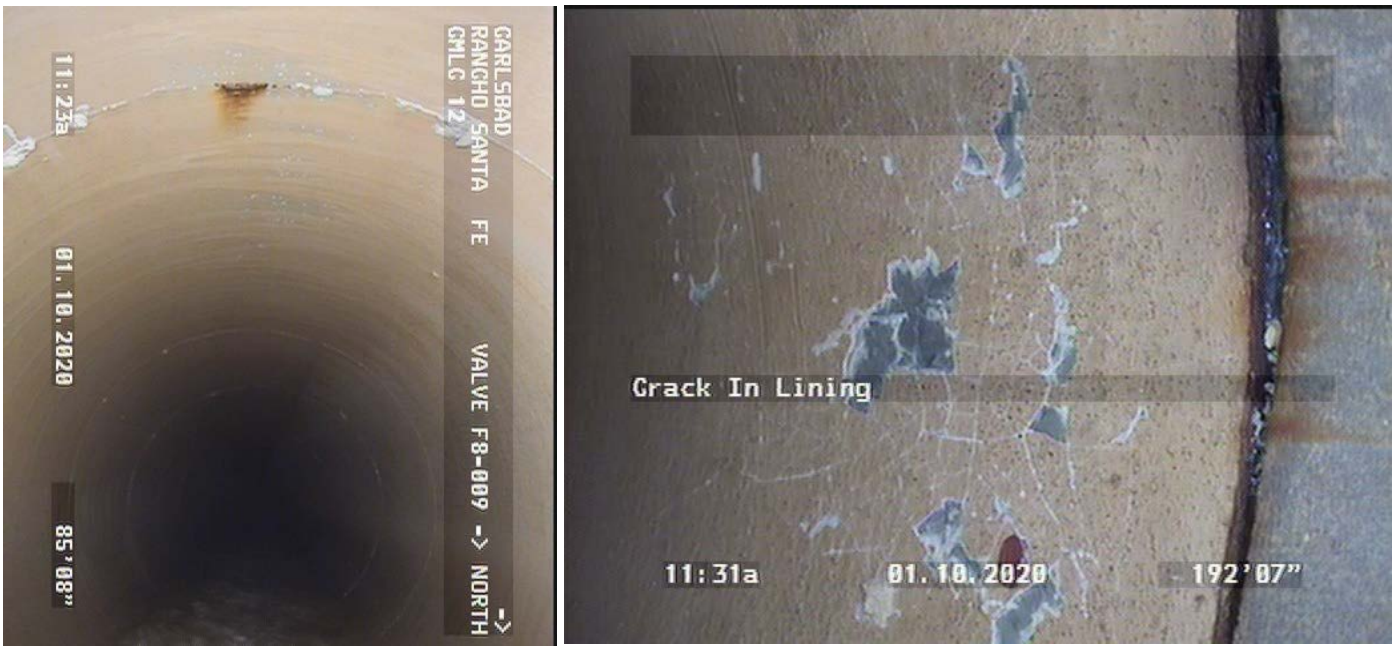


Figure ES 1-4. Group 3 Defect Examples With Minor Rust, Lining Spalling and Missing Mortar at Joints



Repair and investigation costs were compared to pipeline rehabilitation and replacement costs to determine a recommended remediation approach. These costs are summarized in Table ES 1-2. Repair costs are within the range of rehabilitation costs and repair costs are 49 to 84 percent of replacement costs. These repairs will not address joint defects and other minor defects along the pipeline such as Group 3 defects shown in Figure ES 1-4. Performing rehabilitation or replacement of the assessed pipeline is recommended. HDR recommends the District budget for replacement and evaluate lining technologies during the design and planning phase of project delivery.

Table ES 1-2. Defect Remediation Alternatives

Remediation Type	Opinion of Cost	Shut Down Timing	Assumptions
Repair	$840,000	Assumes 2 shut down days per repair. Assumes 8 repairs. 8 shut down days assuming 2 construction crews. 16 shut down days assuming 1 construction crew.	Includes 25% Soft costs, 25% contingency.
Rehabilitation	$660,000 to $1,140,000	Assumes 300 feet per day during shut-down. 6 days.	65% of replacement cost is assumed. Costs typically range from 50% to 75% of replacement costs. Some repairs may be required which would increase costs.
Replacement	$1,000,000 to $1,700,000	Assumes parallel pipeline installed and shut-down occurs during tie-in. 3-5 days.	Includes $30 to $53/Inch-Diameter/LF unit cost, 25% soft costs, 35% contingency. $53/Inch-Diameter/LF based on El Camino Real replacement project. Assumes ~1,600 feet for replacement. Includes external corrosion direct assessment (ECDA) costs.

The inspection findings identified likely construction quality issues. Based on these findings, the portions of the original pipeline construction project that were not inspected are recommended for low-impact assessment in the near-term to prioritize and identify timing for Unit A replacement or rehabilitation. The unassessed portion of the 12-inch Unit A pipeline is 13,233 linear feet. Several assessment alternatives were evaluated and the following low-cost and low-impact alternatives are recommended:

- Annual cathodic protection surveys
- Opportunistic condition assessments during valve replacement, service lateral installation or other opportunities
- Corrosion survey to identify corrosive soil hot spots and potential areas of active corrosion without excavation
- Leak detection

Opinions of cost for the low-impact assessments are $370,000. These costs are an order of magnitude less cost than replacement or rehabilitation which are $7.7 to 13.5 million for replacement and $5.0 to $8.8 million for rehabilitation.

The resulting recommendations for defect remediation and inspection are presented in Table ES 1-3. These timeframes are a conservative assumption of remaining useful life based on the inspection results. The pipelines may last significantly longer without a leak or break. The pipelines may also leak or break sooner.

Table ES 1-3. Pipeline Recommendations and Opinion of Cost

Pipeline	Description	Cost
Near-term (within 3 to 5 years)		
Assessed Portion of Unit A - 12-inch Rancho Santa Fe Rd Pipeline – 1,600 feet	Replace pipeline and perform External Corrosion Direct Assessment (ECDA) on the portions of pipe removed. Replacement includes the 1,401 feet of pipeline assessed plus approximately 200 feet of additional pipeline, to nearest isolation valve. Use ECDA results to help plan future work on the unassessed part of Unit A (As-Built 5515-A in GIS). Consider evaluating rehabilitation lining technology for addressing defects on this pipeline instead of replacement.	$1,000,000 to $1,700,000
Unassessed Portions of Unit A Project – 13,233 feet	Proactively monitor portions of the Unit A project (As-Built 5515-A in GIS) that were not inspected. Perform corrosivity survey and leak detection to prioritize and identify timing for inspection, rehabilitation or replacement projects. Develop and perform an opportunistic condition assessment program for when the pipe is exposed and open such as during valve replacement, break repair, and service lateral installation. Perform annual cathodic protection surveys.	$370,000
	Near-term Total	**$1,370,000 to $2,070,000**
Long-term (5 to 10 years or more)		
Unassessed Portions of Unit A Project – 13,233 feet	Alternative 1 - Replace Unit A based on near-term proactive monitoring.	$7,700,000 to $13,500,000
	Alternative 2 - Evaluate rehabilitation against replacement and rehabilitate Unit A through lining based on near-term proactive monitoring.	$5,000,000 to $8,800,000

1 Introduction

The District operates and maintains over 400 miles of potable water pipeline and 17 water storage reservoirs with a capacity of nearly 80 million gallons of water. In 2017, the District completed a water main risk prioritization study and identified 30 pipeline, totaling 40 miles in length, for more detailed analyses. In 2018, HDR was selected to prepare recommendations and plans for the inspection and condition assessment of the 12-inch Unit A Rancho Santa Fe Road pipeline, along with other pipelines.

The 12-inch Unit A pipeline starts at Las Olas Court and continues south along Rancho Santa Fe Road to Avenida La Posta and Calle Acervo. It is a welded steel CML&C pipeline constructed in 1961 and consists of a mortar-lined mild-steel cylinder that is coated with cement mortar for corrosion protection and impact resistance, and is manufactured in accordance with AWWA C200.This pipeline was installed as part of a larger construction project including several miles of pipeline known as Unit A. Figure 1-1 presents the location of the pipeline in Rancho Santa Fe Road and the assessment extents. Table 1-1 presents additional information on the pipelines.

Video and RFT inspections were performed on the pipeline. This inspection was conducted by PICA in January 2020. HDR tasks included interpreting the inspection data and documenting recommendations for defect repair, inspection, operations and maintenance and opinions of cost. This report documents these findings and recommendations. Also included are recommendations for other Unit A pipelines that may be in similar condition including steel pipeline installed in 1961 on Encinitas Blvd, Rancho Santa Fe Road, Olivenhain Road and South El Camino Real. Three 12-inch CML&C pipelines were identified in the District's request for proposals. These pipelines are included in Unit A. Figure 1-2 documents the extents of Unit A which include pipe installed at the same time and likely by the same contractor. Leak repair records identify the following leaks on the Unit A pipeline. This break data shows relatively few breaks on the pipeline, but a recent break had significant impacts to the District.

- July 2016 – Failed butt strap near the intersection of Rancho Santa Fe Road and Manchester Ave. This break resulted in approximately 690 hours of District labor including 540 hours of overtime. This pipeline is being addressed by a current construction project.
- November 1993
- August 1989
- March 1972
- October 1970
- February 1970

Alternative inspection technologies and how they could be applied to various portions of the 12-inch Rancho Santa Fe pipeline were investigated prior to the inspection work, with the goal of balancing risks, costs, and operational constraints. Among the methods considered were: traditional condition assessment, remote-field electromagnetic scanning, magnetic flux leakage, leak detection, internal visual inspection, and external

direct assessment. Additional methods that were less suited to meet the District's objectives were acoustic velocity, broadband electromagnetic, and in-line ultrasonic. These methods are described in AWWA's Manual M77, "Condition Assessment of Water Mains."

HDR's planning work leading up to the inspections included:

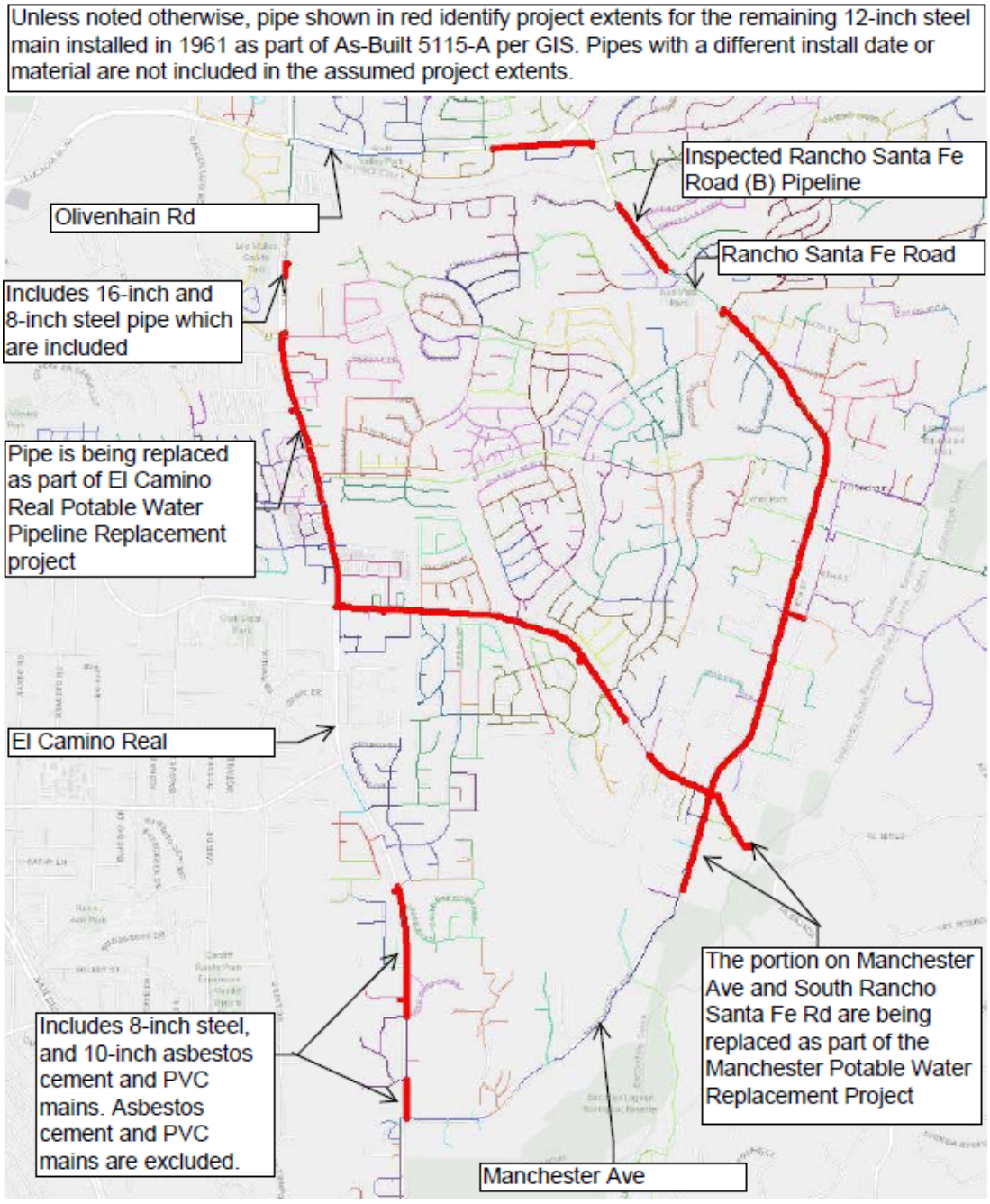
- A review of record drawings and cathodic protection information
- Meetings with District staff
- Conversations / interviews with District engineers
- Field visits and review of pipeline alignments and appurtenances

Figure 1-1. 12-inch Unit A Rancho Santa Fe Road Pipeline

Table 1-1. Pipeline Inspection Information 12-inch Rancho Santa Fe Road Pipeline – Unit A

Alignment Name	Unit A Pipe Length (ft)	Pipe Length Assessed (ft)	Assessed Diameter (in)	Material	Install Year	Cathodic Protection	Assessed Location
Unit A - Rancho Santa Fe Road	14,634	1,401	12	CML&C Steel	1961	Cathodic protection and test stations were installed after initial construction.	Rancho Santa Fe Road from Las Olas Court to Avenida La Posta and Calle Acervo.

Figure 1-2. Project Extents for Unit A



2 Data Review

The District was provided with a request for information list detailing the data necessary for the pipeline inspection and condition assessment analysis. Existing data that were provided and reviewed include:

- 12-inch Record Drawings, 1961
- 12-inch Record Drawings, 1990
- City of Carlsbad Record Drawings, 1997,2001
- Olivenhain Municipal Water District Standard Specifications and Drawings, February 2017
- District Nobel System GeoViewer GIS Access
- District GIS Shapefiles (Water_Shapefiles_11_11_2019)
- District Water Access Database
- Pipeline Repair Records
    - Summary of Break Reports 1964-1995
    - Leaks after 01 21 2016
    - Leaks between 2009 and 01 21 2016

The PICA *Rancho Santa Fe Road 12-in Steel Water Main Condition Assessment Report, Standard Analysis* (PICA Report) and the Houston & Harris video inspection report and video were also reviewed.

3 Inspection Findings

This section summarizes the inspection findings for the 12-inch Unit A Rancho Santa Fe Road pipeline. In January 2020, PICA conducted electromagnetic remote field testing and Houston & Harris conducted CCTV video inspection of portions of the pipeline.

3.1 Electromagnetic Remote Field Testing

PICA conducted electromagnetic RFT inspections of the pipeline using the SeeSnake platform which is shown in Figure 3-1. The purpose of the inspection is to identify steel cylinder corrosion losses.

In electromagnetic scanning, an electromagnetic field is generated by a transmitter and is detected some distance away by an array of receivers. As the field passes through dense materials such as steel, impedance occurs. By measuring and recording the differences in signals received at the array of receivers, thinning of the steel cylinder can be detected.

The strengths and weaknesses of electromagnetic technology are very well established for uniform cylinder pipes, such as welded steel, ductile iron and cast iron, through numerous third-party “dig-up” validations. Likewise, the strengths and weaknesses of

electromagnetic technology are also well established for inspection of PCCP, where electrical currents generated in the wires produce their own electromagnetic fields, which are disrupted when the wires are broken. One weakness is identifying joint corrosion. There are typically two layers of steel pipe at the joints which cause the data to be difficult to evaluate. Joint corrosion can be identified if there is very significant corrosion. Wall loss and remaining pipe wall thickness cannot be determined at joints. There was one joint that may have severe corrosion which is discussed further in Section 3.3.

Figure 3-1. SeeSnake Platform

3.2 Video Inspection

Video inspection of a portion of the pipeline interior was performed prior to the electromagnetic inspection. The purpose of the video inspection was to visually inspect the interior of the pipeline for cracks, lining spalling, joint deterioration, staining, rust, and other defects, and to assure unobstructed passage of the RFT tool. Due to the documented 45 degree bends that prevented a complete inspection, only 318 feet of pipeline were assessed.

3.3 Inspection Defects

Inspection methods are imperfect and there may be hidden, covered, inaccessible or internal material defects that are not being detected. Inspection method limitations and accuracy considerations such as calibration are documented in the PICA inspection report.

The inspection findings are organized by defect severity in order to prioritize defects for repairs and investigations. Each defect was assessed and assigned a defect severity group number. Group 1 defects are urgent or emergencies and are recommended for immediate investigation or repair; Group 2 defects are significant defects that are recommended for near-term investigation or repair; and Group 3 defects are recommended for monitoring on a regular frequency. PICA identified two locations as anomalies that could be indicative of significant wall losses or construction features. These anomalies are recommended for near-term investigation and repair if needed. Table 3-1 includes descriptions of the defect severity Groups 1, 2 and 3 and the count of defects identified for each pipeline.

Table 3-1. Defect Severity Group Descriptions and Counts

Defect Severity Group	Description	Recommended Timeframe	Defect Count
Group 1	An urgent or emergency project is recommended to investigate defect locations identified as Group 1 and repair these locations, if needed.	As Soon As Practicable	0
Group 2	Investigation and repair of defects identified as Group 2 is recommended. Group 2 defects include locations where PICA identified significant wall loss or where video inspection identified significant spalling with bare steel and corrosion. Group 2 defects could be addressed through a future project.	Near-Term Repair and Investigation (Within 3 to 5 years)	16, 13 – PICA, 3 – Video
Group 3	HDR recommends Group 3 defects be monitored in the future. These defects are identified by PICA and video inspection and consist of minor wall loss, cracks, spalling. Group 3 defects also include joints without mortar and rust visible. Corrosion will eventually result in leaks at the joints. Consider monitoring these joints through leak detection or plan for rehabilitation or replacement.	Monitoring (5 Years)	53, 26 – PICA, 3 – Video

Defect Severity Group	Description	Recommended Timeframe	Defect Count
Anomalies	PICA identified two locations as anomalies that could be indicative of significant wall losses or construction features.	Near-Term Investigation and Repair if Needed (Within 3 to 5 years)	2

A summary of the inspection findings by defect severity group are included below. Detailed defect location and information are included in Appendix B.

3.3.1 Group 1 Defects

There were no Group 1 defects identified for the 12-inch pipe. There are locations identified by PICA with significant wall loss that would be considered Group 1 defects for a larger pipeline with higher consequences of failure, such as the 27-inch Unit K or 24-inch Unit B pipelines. However, failure of the 12-inch pipeline is less consequential, particularly given its location less than a quarter mile from District operations yard, enabling rapid response to breaks or leaks, and this section can be bypassed without customer interruption.

3.3.2 Group 2 Defects

There are several locations where PICA's RFT identified significant wall loss or the video revealed bare steel with significant rust. These defects should be repaired or addressed in the near-term. These types of defects could be grouped together and assessed and repaired through a future project. There may be more Group 2 defects located along the portion of the pipeline that was not assessed with video inspection.

There are a total of 16 Group 2 defects identified including 13 identified by PICA and 3 identified through video inspection. A summary of the Group 2 defects includes the following:

- Significant wall loss – There are 8 defects with significant wall loss. These defects have less than or equal to 20 percent remaining wall thickness. Some of these defects may be "through holes" where corrosion completely penetrates the pipe wall. The pipe may not be leaking at these potential through hole locations for the following reasons:
    - The cement mortar lining and cement mortar coating have structural properties that span the through holes while containing the water pressure.
    - External pressure from soil surrounding the pipe also helps by offsetting some of the internal pressure.

  Because the pipeline is cathodically protected, these external defects may be fairly stable and long-lasting. The corrosion may have initiated from defects stemming from the initial pipeline construction in 1961, and largely arrested when cathodic protection was applied years later. These through holes (or near through holes) may have existed for many decades without failure.

- There are 5 defects with less than 35 percent wall remaining and are located within 1 foot of defects with less than or equal to 20 percent remaining wall thickness. The pipeline may fail at these defect locations if the nearby defects with significant wall loss fail.
- Lining Spalling with Bare Steel and Significant Rust – There are 3 cases of lining spalling with significant rust. This is a concern because subsequent corrosion of the steel cylinder will occur, eventually resulting in leakage or rupture of the pipe.

The corrosion or wall loss may be internal or external. The RFT testing cannot distinguish between wall losses on the interior or exterior of the steel cylinder.

3.3.3 Group 3 Defects

Group 3 defects identified by PICA's RFT and video inspections should be monitored in the future for deterioration. There are 53 cases of Group 3 defects identified including 26 identified by PICA and 27 by video inspection. These defects consist of minor defects including cracks, minor lining spalling, and minor rust stains. Group 3 defects also include joints without mortar. Mortar was missing from all joints that were inspected with video. Similar conditions likely exist in the uninspected portions of this main and possibly other similar pipelines. Corrosion will eventually result in leaks at these joints. The District has indicated that repairs have been necessary due to similar unmortared joints.

4 Recommendations and Opinion of Cost

HDR developed recommendations for defect remediation and future inspections, including opinions of cost, for the portion of pipeline that was assessed. HDR also developed inspection recommendations for the portions of pipeline that were not assessed. These recommendations, which are presented in this section, are based on a review of the District's documents including record drawings, the history of repairs to the pipeline, historical data, video inspection report and the condition assessment report by PICA.

These recommendations are intended to provide a basis for budgeting and planning of future defect remediation and inspection activities. As time progresses and additional information is obtained regarding the pipeline condition, these recommendations should be modified to include the updated information.

Alternatives were evaluated for repair recommendations. The recommended repair alternative was then compared to rehabilitation and replacement costs for the assessed pipeline to evaluate and recommend a defect remediation approach. Future inspection recommendations are also included in this section.

Opinions of probable cost are in 2020 dollars and actual costs will vary. These opinions of cost are intended for budgetary and planning purposes. A capital cost factor (soft costs) of 25 percent is applied to each opinion of cost for rehabilitation or replacement to account for additional District capital costs including planning, design, inspection, construction management and contract administration. Repairs and inspection work may or may not be capitalized, but there are still additional soft costs for this work and a soft cost factor of 25 percent is applied when construction is expected. A 10 percent soft cost factor is applied to inspection methods that do not typically require construction, such as a corrosivity survey. A contingency factor of 25 percent is applied for repairs and inspection and 35 percent is applied for rehabilitation and replacement, to account for unforeseen costs identified during design and construction such as additional repairs or investigation needs and site conditions. Repairs have a lower contingency factor than rehabilitation and replacement because more is understood about these potential costs, based on the recent work performed by the District as part of this project.

Unit costs for repairs and condition assessment were developed based on industry experience, discussions with contractor Cass-Arrieta, and reviews of recent costs for condition assessment and repair-related construction costs performed by the District or other utilities. The unit costs and a description of each item are presented in Table 4-1.

Table 4-1. Repair and Condition Assessment Unit Costs

Item	Description	Typical Cost Range	Unit	Assumed Cost
Excavation and repair - Difficult	Includes significant traffic control, limited construction windows, 10-20 ft depth, pavement, striping, curb or median impacts	$80,000 to $100,000	Each	$90,000
Excavation and repair - Moderate	No to low traffic control, 5-20 ft depth, pavement and curb impacts	$50,000 to $80,000	Each	$60,000
Excavation and repair - Low	No traffic control, 0-10 ft depth, no pavement impacts	$30,000 to $50,000	Each	$40,000
External Corrosion Direct Assessment for Buried Pipe	Used to verify defects, remaining wall thickness, pits, pipe coating effectiveness and soil corrosivity. $4500 per location for contractor support (assumes 1 day per location) $9000 per location for assessment work	N/A	Each	$13,500
PICA Electromagnetic Remote Field Testing Inspection	In-pipe inspection tool used to accurately identify pits and remaining wall thickness of the pipe cylinder. PICA inspection ($55/LF), engineering support at (50% PICA inspection costs - $28/LF) and construction support ($52/LF). Work is assumed to be similar to recent inspection work performed by the District. Assumes one access excavation per inspection.	$100 to $200	LF	$135
Video Inspection	In-pipe inspection tool used to identify visual defects such as missing mortar at joints, rust and spalling. Includes $4/LF for inspection vendor and $26/LF for access construction based on recent inspection work performed by District. Access construction assumes access needed every 1,200 to 2,400 feet of inspection, 6-10 feet of excavation, minor traffic control.	N/A	LF	$30
Leak Detection	In-pipe tool used to identify leaks and gas pockets. Assumes leak detection using Xylem Smart Ball or PICA Recon+ tools via existing hydrant insertion and retrieval. Assumes approximately 2,000 feet of leak detection per inspection. The District should also consider lower cost leak detection that can be performed from the surface without accessing the pipeline.	$4 to $30	LF	$20
Corrosion Survey Assessment	Used to identify corrosive soil hotspots and areas of active external corrosion on the pipeline without excavation. Assumes soil corrosivity study with e-mag soil conductivity testing, Wenner 4-Pin Testing, Soil Sample Laboratory testing. Includes baseline electrochemical potential survey, electrical continuity testing, and some close-interval survey if outside of traffic areas, GIS/GPS data integration, and draft/final report of results.	$2 to $6	LF	$2.50
Cathodic Protection Annual Survey	Used to monitor cathodic protection system which arrests external corrosion. Includes potential readings at test stations. Assumes 1 mile or more of readings are performed. The District currently has a cathodic protection survey program.	N/A	LF	$0.20
Opportunistic Condition Assessment	Includes assessment of condition by District staff during opportunity events such as valve replacements, service installations and break response. Includes inserting CCTV push cameras, taking soil samples for testing, visual observations, pipe to soil potential readings, and installing supplemental cathodic protection anodes. Costs are typically less than $1,200 each, if a cathodic protection anode is installed and less than $200 each assessment for soil sampling. There are initial investments required in cameras, training, and data management. Initial costs are assumed to be $25,000 and each opportunity assessment is assumed to be $200 on average since the 12-inch Unit A pipeline has cathodic protection. 5 opportunities on Unit A are assumed per year.	N/A	N/A	$25,000 initial investment and $1000 per year for Unit A

4.1 Unit A Pipeline Recommendations

This section presents recommendations and opinions of cost for the 12-inch Unit A pipeline including opinions of cost for defect remediation and inspection.

4.1.1 Pipeline and Project Extents

Condition assessment inspection of the 12-inch pipeline covered a cumulative distance of approximately 1,401 feet. The pipe was installed in 1961 with project as-built number 5515-A. Analysis of District GIS data and discussions with the District determined there were a total of approximately 14,634 feet of pipe with the same as-built number, same material and installation year that are not currently identified for replacement or in construction. When analyzing the GIS data, portions of the pipeline were removed and these portions are identified in Figure 1-2. There are approximately 6,600 linear feet of asbestos cement pipe that are not included that have as-built number 5515-A and an install year of 1961. These AC pipes will deteriorate differently than the steel pipe and an opportunistic condition assessment program is recommended for these pipelines. Table 4-1 displays the total pipe length of the project for each diameter. Table 4-1 also includes the length assessed and the unassessed lengths that are considered for future assessment in this report. The 90 feet of 4-inch diameter pipe installed on this project is excluded because assessment on this size pipe is not practical.

Table 4-2. Project Length – As-built 5515-A

Pipe Diameter (in)	Pipe Length (ft)	Assessed Length (ft)	Unassessed Length
8	1,502		1,502
10	166		166
12	12,753	1,401	11,352
16	213		213
Total Length (ft)	**14,634**	**1,401**	**13,323**

4.1.2 Recommendations and Opinions of Cost for Assessed Pipeline

Alternatives for the remediation and reassessment of the 12-inch pipeline are evaluated in this section. The District has performed video inspection and PICA RFT inspection which provide adequate information for sound remediation and inspection decision making. Included in this section are the following alternatives:

1. **No Additional Action** –This alternative includes continuing the District's annual cathodic protection survey and operation of the pipeline until it breaks one or multiple times prior to planning replacement. Although severe defects were identified in the PICA inspection, the pipeline may operate without leaks or breaks for many years, due to its cathodic protection. The costs for future breaks and resulting impacts are unknown at this time. The Unit A pipeline has experienced relatively few breaks, but a recent break in summer 2016 had a significant impact on the District.

2. **Repair and Investigate –** Perform repairs and external corrosion direct assessment (ECDA) investigations on significant defects.
3. **Rehabilitate –** Line the pipeline to address significant and minor defects, including lack of mortar at the joints.
4. **Replacement** – Replace the pipeline to address all defects

Alternatives for repairs, rehabilitation and replacement are evaluated in the following sections and costs are compared. Future inspection recommendations and opinions of cost are also included in this section.

4.1.2.1 Repair and Investigate

Costs were estimated for the following repair and investigate alternatives for use in developing a recommended alternative.

- **Alternative 1** - Repair Group 2 defects identified by PICA RFT and video inspections. Perform ECDA of two anomalies prior to repair and perform ECDA investigation of pipe removed after repairs.
- **Alternative 2** - Repair only the Group 2 defects identified by PICA. Perform ECDA investigation of pipe removed after repair.

Alternative 1 is recommended for comparison with rehabilitation and replacement because it addresses the severe Group 2 defects and provides good value to the District for verifying defects and planning future assessments and remediation of the Unit A project extents.

Opinions of cost for each repair and investigation alternative is summarized in Table 4-3 including estimates of pipeline shutdown durations. Detailed recommendations for each defect are documented in Appendix B along with ECDA locations. Each of the nine joints inspected had missing mortar and visible rust. This indicates that joints along other Unit A segments likely have similar joint defects. Corrosion will eventually result in leaks at these joints and such corrosion is not slowed by the existing cathodic protection system. The District should consider monitoring joints through leak detection or plan for rehabilitation or replacement.

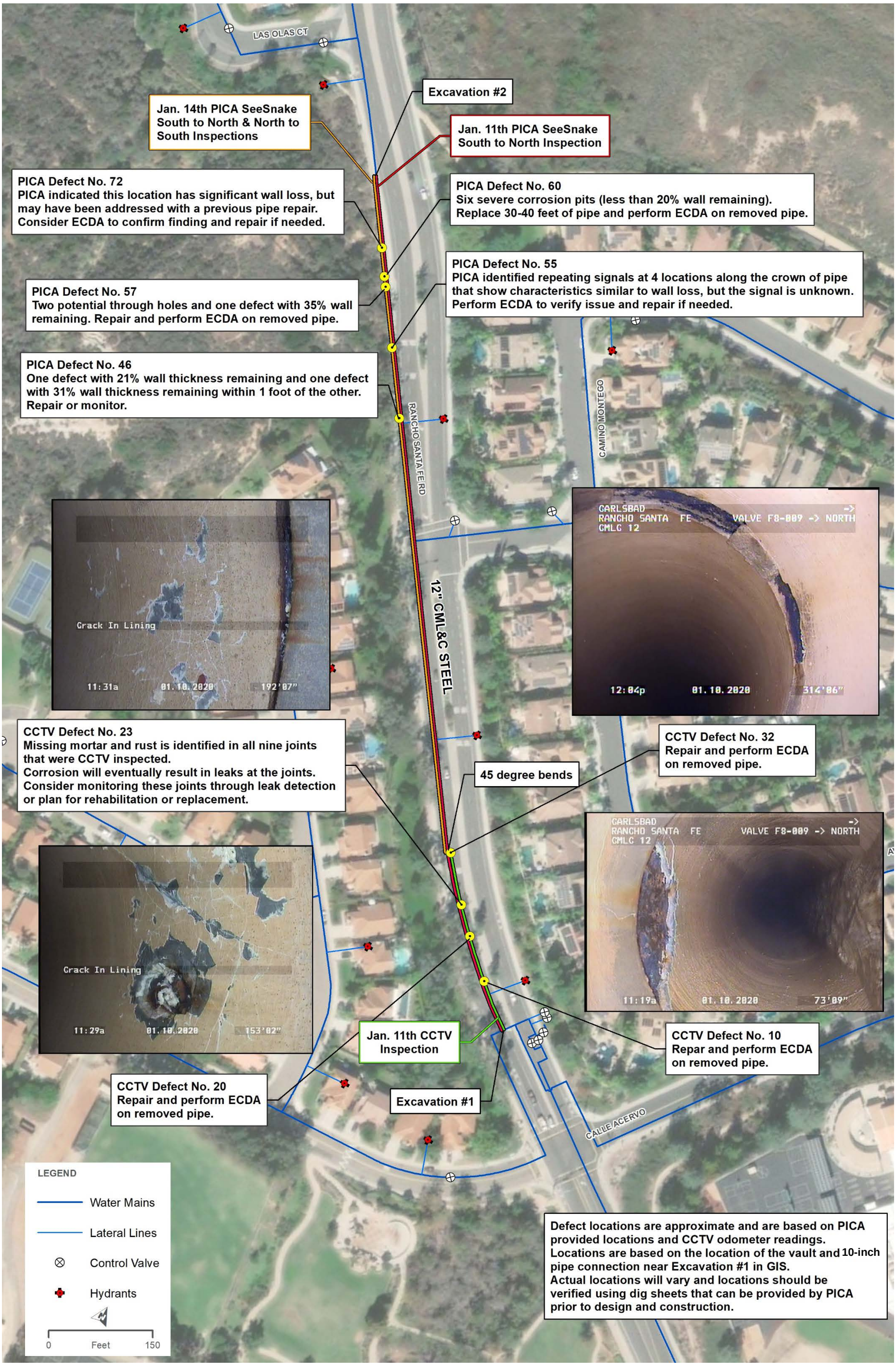
Figure 4-1 presents video images and PICA defect locations for the recommended alternative for repair. Defect numbers in the figures correspond to defect numbers in Appendix B. Defect locations in the figures are approximate and are based on video odometer footages and PICA provided locations. Actual defect locations will vary and should be identified prior to construction through dig sheets that PICA can provide.

Table 4-3. Repair Alternatives for Assessed 12-Inch Pipeline

No.	Repair Cost - PICA and Video Defects and Anomalies	Repair Cost - PICA Defects	ECDA of Repaired Pipe After Removal[1]	ECDA of PICA Identified Anomolies [2]	Total Cost	Shut Down Timing
1	$800,000	N/A	$16,000	$27,000	$843,000	Assumes 2 shut down days per repair. Assumes 8 repairs. 8 shut down days assuming 2 construction crews. 16 shut down days assuming 1 construction crew.
2	N/A	$330,000	$8,000	N/A	$338,000	Assumes 2 shut down days per repair. Assumes 3 repairs. 6 shut down days assuming 2 construction crews. 3 shut down days assuming 1 construction crew.

Notes:
1. Assumes ECDA of 6 short pipe segments up to 6 feet long and one long pipe segment up to 40 feet long for Alternative 1. Assumes ECDA of 2 short pipe segments up to 6 feet long and one long pipe segment up to 40 feet long for Alternative 2. Includes chemistry testing of mortar at two depths, soil sample test, removing mortar and verifying remaining wall thickness. Assumes 4 days of work by HDR staff for Alternative 1 and 2 days of work for Alternative 2 and draft/final report.
2. Assumes ECDA for two anomalies identified by PICA. ECDA is assumed to be performed in open trench prior to potential repair work.

Figure 4-1. Repair and Investigation Locations



4.1.2.2 Rehabilitation and Replacement of Assessed Pipeline

HDR prepared opinions of cost for rehabilitation and replacement alternatives for comparison to repair costs to determine whether the pipeline should be repaired or whether the District would get more value from rehabilitation or replacement.

The following assumptions are made for rehabilitation and replacement:

- Pipe will be replaced or rehabilitated to the isolation valve on Las Olas Court. This adds approximate 200 feet to the replacement length.
- Replacement cost per inch-diameter per foot is $30 to $53. The $53 per inch-diameter per foot is based on recent pipeline replacement and street repaving costs on El Camino Real.
- Additional capital cost factor is 25 percent for additional District capital costs including planning, design, construction management and contract administration
- Contingency is 35 percent.
- The portion of replacement cost assumed for rehabilitation is 65 percent. Rehabilitation is assumed to be performed through cured-in-place or close-fit slip-lining. Typical rehabilitation costs can range from 50 to 75 percent of replacement cost for pipeline of this size. Rehabilitation technologies will result in reduced hydraulic capacity. Cured-in-place lining should not be considered equivalent to a new pipe.

The opinion of cost is presented in Table 4-4 for rehabilitation and replacement. The replacement cost range is approximately $1.0 to 1.7 million.

Table 4-4. Rehabilitation and Replacement 12-inch Unit A Assessed Pipeline

Diameter (inch)	Length (ft)	Cost per inch-diameter per foot	Subtotal	Additional Capital Costs (25%)	Contingency (35%)	Total Replacement Cost	Total Rehabilitation Cost (65% of Replacement)
12	1,601	$30	$580,000	$150,000	$260,000	$990,000	$640,000
12	1,601	$53	$1,020,000	$260,000	$450,000	$1,730,000	$1,120,000

4.1.3 Remediation Comparison for Assessed Pipeline

Table 4-5 compares the costs and shutdown durations for (1) repair and investigate, (2) replacement and (3) rehabilitation. The repair alternative is not recommended for the following reasons:

- Repair costs are within the range of rehabilitation costs.
- Repair costs are 49 to 84 percent of replacement costs.
- The repair alternative will not address joint defects and other minor defects along the pipeline.

Performing rehabilitation or replacement of the assessed pipeline is recommended. The District is currently considering rehabilitation technologies for pipeline remediation. HDR recommends the District budget for replacement and evaluate lining technologies during the design and planning phase of project delivery.

Table 4-5. Remediation Alternatives Summary for Assessed 12-inch Pipeline

Remediation Type	Remediation Cost	ECDA of Repaired Pipe After Removal Cost[1]	ECDA of PICA Identified Anomalies Cost[2]	Total Cost	Shut Down Timing	Assumptions
Repair	$800,000	$16,000	$27,000	$843,000	Assumes 2 shut down days per repair. Assumes 8 repairs. 8 shut down days assuming 2 construction crews. 16 shut down days assuming 1 construction crew.	Includes 25% Soft costs, 25% contingency.
Rehabilitation	$640,000 to $1,120,000	$16,000	N/A	$656,000 to $1,136,000	Assumes 300 feet per day during shut-down. 6 days.	65% of replacement cost is assumed. Costs typically range from 50% to 75% of replacement costs. Some repairs may be required which would increase costs.
Replacement	$990,000 to $1,730,000	$16,000	N/A	$1,006,000 to $1,746,000	Assumes parallel pipeline installed and shut-down occurs during tie-in. 3-5 days.	Includes $30 to $53/Inch-Diameter/LF unit cost, 25% capital costs, 35% contingency. Includes ~1,601 feet of replacement

Notes:
1. Assumes ECDA of 6 short pipe segments up to 6 feet long and one long pipe segment up to 40 feet long. Includes chemistry testing of mortar at two depths, soil sample test, removing mortar and verifying remaining wall thickness. Assumes 4 days of work by HDR staff and draft/final report.
2. Assumes ECDA for two anomalies identified by PICA. ECDA is assumed to be performed in open trench prior to potential repair work.

4.1.4 Recommendations for Unit A Pipeline Project Extents

The condition of the assessed portion of the pipeline could be representative of the condition of other portions of the pipeline installed as part of the same project. Construction practices have a significant impact on the performance of the pipeline. PICA identified defects that could be caused by construction practices. If similar construction practices occurred throughout the project, it is likely there are similar defects throughout the project. Consequently, HDR recommends the District perform proactive monitoring or condition assessment on the 13,233 feet of pipe that has not been assessed if practical. Alternatives for the assessment of the Unit A project extents are evaluated in this section.

Assessment alternatives include the following. The costs for the alternatives are summarized in Table 4-6 and unit costs are included in Table 4-1. HDR recommends the District consider proactive monitoring of Unit A using Alternatives 1, 2, 3 and 4 to prioritize and plan the timing for future replacement or rehabilitation of Unit A.

1. **Annual Cathodic Protection Survey –** This alternative is used to monitor cathodic protection system performance and arrest corrosion without pipeline excavation or shut downs. The District currently has a cathodic protection survey program. HDR recommends the District perform annual cathodic protection surveys on Unit A. This approach will not arrest all corrosion and there may be future breaks. In particular, cathodic protection is not effective for internal corrosion stemming from mortar defects and unmortared joints. The costs for future breaks and resulting impacts are unknown at this time. The Unit A pipeline has experienced relatively few breaks, but a recent break in summer 2016 had a significant impact on the District. The costs for this alternative are low and value is high with respect to mitigating corrosion damage.
2. **Opportunistic condition assessment** – Includes assessment of condition by District staff during opportunity events such as valve replacements, service installations and break repairs. Opportunity condition assessment is cost effective. Typically 90 percent of the cost of condition assessment stems from excavation to gain access to the pipeline. These costs are eliminated when data are collected when the pipe is already exposed. Opportunity assessment can include inserting push cameras to inspect joints, collecting soil samples for laboratory testing, visual observations and photographs, taking pipe-to-soil potential readings, and installing sacrificial cathodic protection anodes. This approach is recommended for Unit A. The District should also consider incorporating this approach for other pipelines.
3. **Corrosivity Survey** – Identifies corrosive soil hotspots and areas of active external corrosion on the pipeline without excavation or shut downs. Includes soil corrosivity study with e-mag soil conductivity testing, Wenner 4-Pin Testing, and Soil Sample Laboratory testing. Includes baseline electrochemical potential survey, electrical continuity testing, and some close-interval survey if the pipe is located outside of high-traffic areas. This approach will not find all defects, but is cost effective and is recommended for prioritizing parts of Unit A for replacement or rehabilitation.

4. **Leak Detection** – This alternative includes performing regular leak detection to identify leaks. Joint defects and small defects on welded steel pipe typically leak before rupturing. However, ruptures may occur without warning. Use of in-pipe detection tools requires some flow management, but excavations are generally not required if existing hydrants can be used for insertion and extraction. Leak detection is recommended for identifying the timing for rehabilitation or replacement of Unit A. Unit costs for leak detection assume in-pipe leak detection to be conservative, but leak detection may be performed from the surface without accessing the pipe for lower cost. This lower cost leak detection is less precise than in-pipe leak detection. It work better on smaller diameter pipes, such as the 12-inch pipeline, than on larger pipelines.
5. **Video Inspection** – Proactive video inspection is not recommended at this time because of the cost to excavate and insert cameras into the pipelines. However, opportunistic video inspection is recommended to verify joint and lining condition.
6. **Electromagnetic Remote Field Testing –** Not recommended at this time. Based on the results of the recent inspection and construction practices at the time, it is likely the rest of Unit A is in similar condition as the inspected pipeline. A lower cost approach is to monitor and assess the extents of Unit A to prioritize replacement is likely a better value for the District.

Table 4-6. Assessment Alternatives for Unit A Project Extents

Inspection Alternatives	Recommended	Length	Unit Cost	Subtotal	Subtotal with Additional Soft Costs[1]	Contingency (25%)	Total Cost
1. Annual Cathodic Protection Survey	Yes	13,233	$0.20	$2,647	$2,911	$728	$3,700
2. Opportunistic Condition Assessment	Yes	N/A	$26,000	$26,000	$28,600	$7,150	$36,000
3. Corrosivity Survey	Yes	13,233	$2.50	$33,082	$36,391	$9,098	$46,000
4. Leak Detection	Yes	13,233	$15.00	$198,494	$218,344	$54,586	$280,000
						Total for Recommended Alternatives	**$370,000**
Other Alternatives							
5. Video Inspection	No	13,233	$30	$396,989	$496,236	$124,059	$630,000
6. Electromagnetic Remote Field Testing	No	13,233	$134.00	$1,773,217	$2,216,522	$554,130	$2,780,000

Notes:
1. Assume 10 percent for Alternatives 1, 2, 3 and 4 because construction is not required. Assume 25 percent for Alternative 5 and 6 because construction is required.

Rehabilitation and replacement costs for Unit A project extents are summarized in Table 4-7 and Table 4-8. Table 4-7 includes the low-range unit cost of $30 per inch-diameter per foot and Table 4-8 includes the high-range unit cost of $53 per inch-diameter per foot. The replacement cost range is $8.6 to $15.3 million.

Shut down requirements for rehabilitation of Unit A are significant and are assumed to be approximately 43 days using 300 feet of lining progress per day. Alternatively, a temporary bypass piping system would be installed along the side of the road. For the replacement alternative, the shutdown duration is assumed to be 1-2 days per parallel pipe segment installation, with multiple shut downs of this duration required for tie-ins.

Table 4-7. Rehabilitation and Replacement Low Range – Unit A Project Extents

Pipeline Description	Length (ft)	Cost per inch-diameter per foot	Subtotal	Subtotal with Additional Capital Costs (25%)	Contingency (35%)	Total Replacement Cost	Total Rehabilitation Cost (65% of Replacement)
12-Inch Assessed Portion and Additional ~200 feet of Pipe to Isolation Valve at Las Olas Court	1,600	$30	$580,000	$730,000	$260,000	$990,000	$640,000
Subtotal for Assessed Pipeline	*1,600*		*$580,000*	*$730,000*	*$260,000*	*$990,000*	*$640,000*
16-Inch Project Extents - Unit A	213	$30	$100,000	$130,000	$50,000	$180,000	$120,000
12-Inch Project Extents - Unit A	11,152	$30	$4,010,000	$5,010,000	$1,760,000	$6,770,000	$4,400,000
10-Inch Project Extents - Unit A	166	$30	$50,000	$60,000	$30,000	$90,000	$60,000
8-Inch Project Extents - Unit A	1,502	$30	$360,000	$450,000	$160,000	$610,000	$400,000
Subtotal for Unassessed Unit A Project Extents	*13,033*		*$4,520,000*	*$5,650,000*	*$2,000,000*	*$7,650,000*	*$4,980,000*
Total for Unit A	**14,633**		**$5,100,000**	**$6,380,000**	**$2,240,000**	**$8,640,000**	**$5,620,000**

Table 4-8. Rehabilitation and Replacement High Range – Unit A Project Extents

Pipeline Description	Length (ft)	Cost per inch-diameter per foot	Subtotal	Subtotal with Additional Capital Costs (25%)	Contingency (35%)	Total Replacement Cost	Total Rehabilitation Cost (65% of Replacement)
12-Inch Assessed Portion and Additional ~200 feet of Pipe to Isolation Valve at Las Olas Court	1,600	$53	$1,020,000	$1,280,000	$450,000	$1,730,000	$1,120,000
Subtotal for Assessed Pipeline	*1,600*		*$1,020,000*	*$1,280,000*	*$450,000*	*$1,730,000*	*$1,120,000*

Pipeline Description	Length (ft)	Cost per inch-diameter per foot	Subtotal	Subtotal with Additional Capital Costs (25%)	Contingency (35%)	Total Replacement Cost	Total Rehabilitation Cost (65% of Replacement)
16-Inch Project Extents - Unit A	213	$53	$180,000	$230,000	$90,000	$320,000	$210,000
12-Inch Project Extents - Unit A	11,152	$53	$7,090,000	$8,860,000	$3,110,000	$11,970,000	$7,780,000
10-Inch Project Extents - Unit A	166	$53	$90,000	$110,000	$40,000	$150,000	$100,000
8-Inch Project Extents - Unit A	1,502	$53	$640,000	$800,000	$280,000	$1,080,000	$700,000
Subtotal for Unassessed Unit A Project Extents	*13,033*		*$8,000,000*	*$10,000,000*	*$3,500,000*	*$13,500,000*	*$8,780,000*
Total for Unit A	**14,633**		**$9,020,000**	**$11,280,000**	**$3,950,000**	**$15,250,000**	**$9,910,000**

Replacing or rehabilitating Unit A would proactively address defects before they fail. There is value to the District in proactively monitoring these pipelines with low-impact assessments in the near term and prioritizing reaches for future rehabilitation or replacement. The costs to perform monitoring are an order of magnitude less expensive than rehabilitation or replacement. However, a monitoring approach may result in additional pipe breaks.

HDR recommends the District consider monitoring the Unit A pipelines and begin planning portions of Unit A for replacement and rehabilitation. If a break on Unit A is an unacceptable risk, the District should plan for replacement and rehabilitation in the near future. On the other hand, the District may choose to wait until failures begin before constructing a new pipeline. The existing cathodic protection system may enable many more years of service. Leakage at the joints, however, is inevitable (while unpredictable).

4.1.5 Operation and Maintenance Recommendations

HDR has identified operation and maintenance recommendations to extend useful service lives and mitigate the consequence of a failure if a failure were to occur. These recommendations include the following:

- The District should consider having repair materials on hand in case of a failure on this pipeline in the near term. Repair materials could include external reinforcing bands and full pipe segments. This will reduce the lead time for acquiring repair materials.
- Pressure reduction was considered, but is not recommended because it will limit the operations of this transmission main.

4.1.6 Recommendations Summary

A summary of the recommendations for Unit A are documented in Table 4-9. These timeframes are a conservative assumption of remaining useful life based on the inspection results. The pipelines may last significantly longer without a leak or break. The pipelines may also leak or break sooner.

Table 4-9. Pipeline Recommendations and Opinions of Cost

Pipeline	Description	Cost
Near-term (within 3 to 5 years)		
Assessed Part of Unit A - 12-inch Rancho Santa Fe Rd Pipeline – 1,600 feet	Plan to replace ~1,600 feet of pipeline and perform External Corrosion Direct Assessment (ECDA) on portions of pipe removed. Replacement includes the 1,401 feet of pipeline assessed plus approximately 200 feet of additional pipeline, to nearest isolation valve. Use ECDA results to plan future work on the unassessed part of Unit A (As-Built 5515-A in GIS). Consider evaluating rehabilitation lining technology for addressing defects on this pipeline instead of replacement. The exact timing of the project depends on the District's ability to tolerate breaks on this pipeline.	$1,000,000 to $1,700,000
Unassessed Part of Unit A Project Extents – 13,233 feet	Proactively monitor the Unit A project extents (As-Built 5515-A in GIS) that was not inspected. Perform corrosivity survey and leak detection to prioritize and identify timing for inspection, rehabilitation or replacement projects. Consider leak detection methods that do not require pipe access. Develop and perform an opportunistic condition assessment program for when the pipe is exposed and open such as during valve replacement, break repairs, and service lateral installations. Perform annual cathodic protection surveys.	$370,000
	Near-term Total	**$1,370,000 to $2,070,000**
Long-term (5 to 10 years or more)		
Unassessed Part of Unit A Project Extents – 13,233 feet	Alternative 1 - Replace Unit A based on near-term proactive monitoring.	$7,700,000 to $13,500,000
	Alternative 2 - Evaluate rehabilitation against replacement and rehabilitate Unit A through lining based on near-term proactive monitoring.	$5,000,000 to $8,800,000

4.2 Lessons Learned

Lessons learned that can be applied to future District condition assessment projects were identified throughout the project and are documented in Table 4-10.

Table 4-10. Lessons Learned

No.	Lesson Learned	Recommendation
1	The PICA inspection tool became lodged in the pipe and required additional excavation and overtime work to remove the tool. Additional steps could be taken in the future to mitigate this risk.	1. District GIS does not show all bends and information included on As-built drawings. Include features and appurtenances that could impact in-pipe assessment from the as-builts into GIS based figures. 2. Develop a risk register with mitigation plan prior to inspection to evaluate risks and identify contingency plan actions. This could be a simple table with the risk and action to be taken if the risk is realized in the field. An example risk register item and contingency plan could include the following: Risk: Tool becomes lodged in pipe Mitigation Actions and Contingency Plans: i. Plan for second excavation as part of inspection. ii. Plan for two winches and dual tethered inspection configuration to reduce risk. iii. If video inspection cannot be performed prior to inspection, abandon inspection and reschedule after video inspection can be performed. iv. If gauge run cannot be performed prior to inspection, abandon inspection and reschedule after gauge run can be performed. v. If isolation valve leak by is significant, abandon inspection and replace valve prior to inspection.
2	Contracting approach put risk and management requirements on the District because they were managing the inspection vendor, contractor and engineering support contracts.	1. Structure contract so consultant hires inspection vendor and contractor.
3	Cleanliness and safety of inspection could be improved	1. Include in future contract language requirements for site safety and disinfection of tools, tether lines, equipment, and staff entering pipelines. 2. Consider appointing a person responsible for disinfection of equipment and staff entering pipelines.
4	Consider future inspection needs during planning and execution.	1. Install manways or access for inspection work that is large enough to accommodate future video and future RFT inspection where appropriate. Remote field testing tools currently require a size-on-size 45-degree wye or removal of approximately 8-10 feet of pipe for inspection. In the future, include installation of a size-on-size wye when repairing the access opening to facilitate future inspections for smaller diameter pipe.

4.3 Additional Recommendations

In addition to planning for regular appurtenance repairs, materials should be stockpiled and funding should be reserved for emergency repairs. In order to make repairs quickly, the following resources are recommended:

- A written emergency response plan, with procedures, responsibilities, contract information, and plans

- Dewatering plans and blanket discharge permit
- Ready access to appropriate contract services
- Excavation and shoring capabilities
- Dewatering pumps, dechlorination, and other treatment equipment
- Welding services
- Steel pipe fabrication
- Concrete and controlled low-strength material (slurry)
- Repair materials
  - Steel pipe spools, mortar lined and coated, to replace full-length pipe segments
  - Internal repair bands
  - External repair bands
  - Butt-strap couplings
  - Internal joint seals (i.e., “Weko seal”)
  - Hydrophilic grout
  - Miscellaneous steel plate and bar stock and welding rods for implementing repairs
  - Rebar for construction of pipe collars and thrust restraints
  - Coating and lining materials with appropriate NSF61 certifications, including epoxy coating, mortar, and joint sealant
- Materials need to be stored in a manner that protects them from degradation and assures that they are readily available for emergency repairs. Warehouse storage is recommended, along with a system that assures that the inventory does not become depleted over time. If warehouse storage of the pipeline segments is not practical, they can be buried in sand. Burying the pipes in sand may not be a common practice and consideration for marking locations of buried pipelines should be considered. Long-term exposure to the sun should be avoided.

4.4 Condition Assessment of Other Transmission Mains

HDR reviewed the Xylem *Water Main Risk Prioritization Report.* This reports identifies the highest risk 30 pipelines in Appendix M and these pipelines are mapped in Appendix L of the report. Some of these pipelines have been assessed as part of this project or currently have pipeline replacement projects in progress. Additional high-risk pipelines on the list include those listed below. The District should consider including condition assessment of these pipelines as part of proactive monitoring and condition assessment plans.

- Mount Israel Road – 10-inch steel

- Via Ambiente – 12-inch ductile iron
- Elfin Forest Rd – 12-inch steel
- Village Park Way – 24-inch and 20-inch ductile iron and asbestos cement
- Circa Oriente – 14-inch and 18-inch asbestos cement
- Levante Street – 12-inch and 14-inch asbestos cement
- South Rancho Santa Fe Road – 12-inch and 18-inch asbestos cement
- Del Dios Hwy – 27-inch steel
- Camino Sin Puente – 18-inch ductile iron
- La Noria and Escondido Creek – 12-inch asbestos cement

5 Conclusions

Through completion of this work, the District is implementing industry best practices to proactively address aging pipeline condition before failures occur.

Video and electromagnetic remote field testing inspections of portions of the 12-inch Unit A pipeline on Rancho Santa Fe Rd were performed. The inspection results were used to identify remediation recommendations for the assessed pipeline as well as the project extents for Unit A. Inspections identified several locations with significant wall loss and visible bare steel and rust at the joints. Repair costs were evaluated against pipeline rehabilitation and replacement remediation recommendations to identify a recommended defect remediation approach. Repair costs are 49 to 84 percent of replacement costs so replacement is recommended. However, rehabilitation through lining could result in significant savings and should be evaluated during planning and design.

The inspection findings identified defects due to construction practices. Based on these findings, the portions of the original Unit A pipeline construction project that were not inspected as part of this project are recommended for proactive monitoring that can be used to prioritize and plan future rehabilitation or replacement. Several condition assessment methods were evaluated and the following low-impact monitoring methods are recommended. HDR recommends the District consider monitoring the Unit A pipelines and begin prioritizing and planning portions of Unit A for replacement and rehabilitation. If a break on Unit A is not an acceptable risk to the District, HDR recommends the District plan for replacement and rehabilitation in the near future.

- Annual cathodic protection surveys – The District currently has a program in place.
- Opportunistic condition assessment during valve replacement, service lateral installation or other opportunities where the pipeline is exposed
- Corrosion survey to identify corrosive soil hot spots and potential areas of active corrosion
- Leak detection survey – Consider lower cost leak detection methods that can be performed from the surface during assessment planning.

Depending on the results of these assessments, excavations for spot repairs and external direct assessments may be appropriate.

The recommended near-term approach (within 3 to 5 years) is to replace or rehabilitate the assessed part of Unit A and perform proactive monitoring of the unassessed part of Unit A. The opinion of cost for replacement is $1.0 to $1.7 million. The opinion of cost for proactive monitoring of the unassessed part of Unit A is $370,000.

The recommended long-term approach (5 to 10 years or more) is to prioritize and plan replacement or rehabilitation of the unassessed part of Unit A using the results of proactive monitoring. The opinions of cost for replacement and rehabilitation are $7.7 to $13.5 million and $5.0 to $8.8 million respectively.

Additional recommendations include:

- Complete regular cathodic protection surveys and evaluation of data to monitor cathodic protection system and arrest corrosion. Annual surveys are recommended for these critical pipelines.
- Plan for regular appurtenance repairs and emergency pipeline repairs. Materials should be stockpiled and funding should be reserved for emergency repairs.
- Incorporate other high risk pipelines into proactive condition assessment and monitoring plans.

Appendix A. Video Inspection Report

Houston & Harris PCS, Inc.
21831 Barton Rd.
Grand Terrace, CA 92313
Tel: 909-422-8990
Fax: 909-422-0841
Email: info@houstonandharris.com

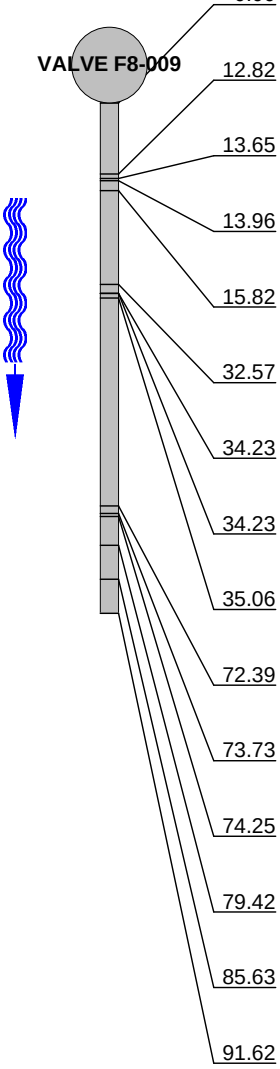
Inspection Report

Date:	Job # :	Weather :	Operator :	Section # :	Project Name :
1/10/2020		**sunny, dry**	**SEAN T**	**1**	**RSF PIPE ASSESSMENT**
Start Station # :	End Station # :	Sheet # :	Drawing # :	Cleaned :	Asset ID

Street 1 :	**RANCHO SANTA FE**	Start Map Pg. :		From MH :	**VALVE F8-009**
Street 2:		End Map Pg. :		To MH :	**NORTH**
City :	**CARLSBAD**	VCR # :		Section length :	**317.89 ft**
Insp. method :		Media # :		Joint length :	

Reason of inspection :		Pipe shape :	
Section type :		Pipe size :	**12 inch**
Area :		Pipe material :	**CMLC**
		Lining :	

Remarks : **RSF PIPE ASSESSMENT**



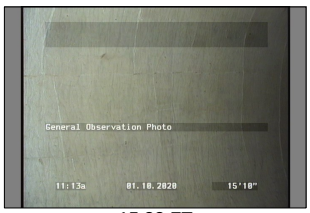
1:414 Position	Code	Observation	Rate
0.00	ST	Begin Inspection At Upstream Manhole / VALV F8-009	
12.82	GO	General Observation Photo / BOTTOM OF PIPE	
13.65	GO	Note: / BOTTOM OF PIPE	
13.96	SVC	Service / 12 O'CLOCK	
15.82	GO	General Observation Photo	
32.57	GO	General Observation Photo	
34.23	GO	General Observation Photo	
34.23	JT	Joint	
35.06	CIL	Crack In Lining / TOP OF PIPE	
72.39	CIL	Crack In Lining / TOP OF PIPE	
73.73	CIL	Crack In Lining / TOP OF PIPE	
74.25	JT	Joint	
79.42	CIL	Crack In Lining	
85.63	GO	Note: / RUST VISIBLE	
91.62	GO	Note: / RUST VISIBLE	

12.82 FT

13.65 FT

13.65 FT

13.96 FT



15.82 FT

City : CARLSBAD

Houston & Harris PCS, Inc.
21831 Barton Rd.
Grand Terrace, CA 92313
Tel: 909-422-8990
Fax: 909-422-0841
Email: info@houstonandharris.com

Inspection Report

Date :	Job number :	Weather :	Operator :	Counter :	Section name :
1/10/2020		**sunny, dry**	**SEAN T**	**1**	
Present :	Vehicle :	Camera :	Preset :	Cleaned :	Rate :

1:414 Position	Code	Observation	Rate
98.66	SVC	Service / 3 O'CLOCK	
102.48	CIL	Crack In Lining / BOTTOM OF PIPE	
113.13	JT	Joint	
151.29	CIL	Crack In Lining / TOP OF PIPE	
153.15	JT	Joint	
153.15	CIL	Crack In Lining / TOP OF PIPE	
166.29	GO	Note: / RUST VISIBLE	
168.56	GO	Note: / RUST VISIBLE	
192.45	JT	Joint	
192.55	CIL	Crack In Lining / TOP OF PIPE	
231.75	JT	Joint	
271.04	JT	Joint	
289.66	GO	Note: / RUST VISIBLE	
310.75	JT	Joint	
310.86	CIL	Crack In Lining / CHIP	
311.99	GO	Note: / BEND TO RIGHT	
313.34	GO	Note: / CHIP IN PIPE	
314.89	JT	Joint	

City : CARLSBAD

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Grand Terrace, CA 92313
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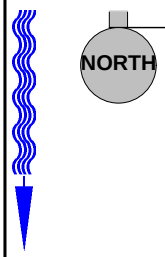
Fax: 909-422-0841
Email: info@houstonandharris.com

Inspection Report

Date :	Job number :	Weather :	Operator :	Counter :	Section name :
1/10/2020		**sunny, dry**	**SEAN T**	**1**	
Present :	Vehicle :	Camera :	Preset :	Cleaned :	Rate :

1:414	Position	Code	Observation	Rate
	317.89	GO	Note: / CAMERA FLIP AT BEND	



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Inspection Pictures

City :	Street :	Date :	Section # :	Section name :
CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

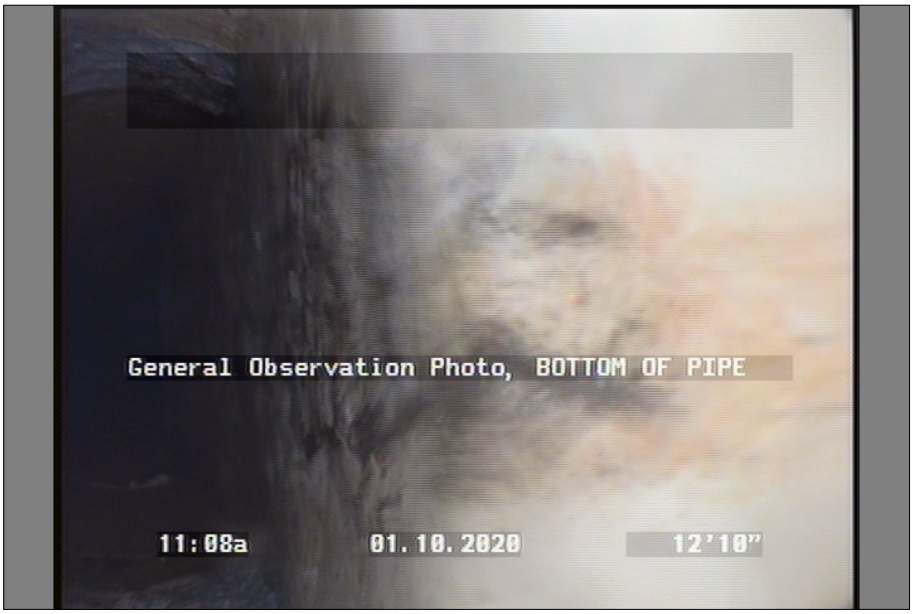

Photo: VALVE F8-009-NORTH-D-12.8231-110705.JPG
General Observation Photo

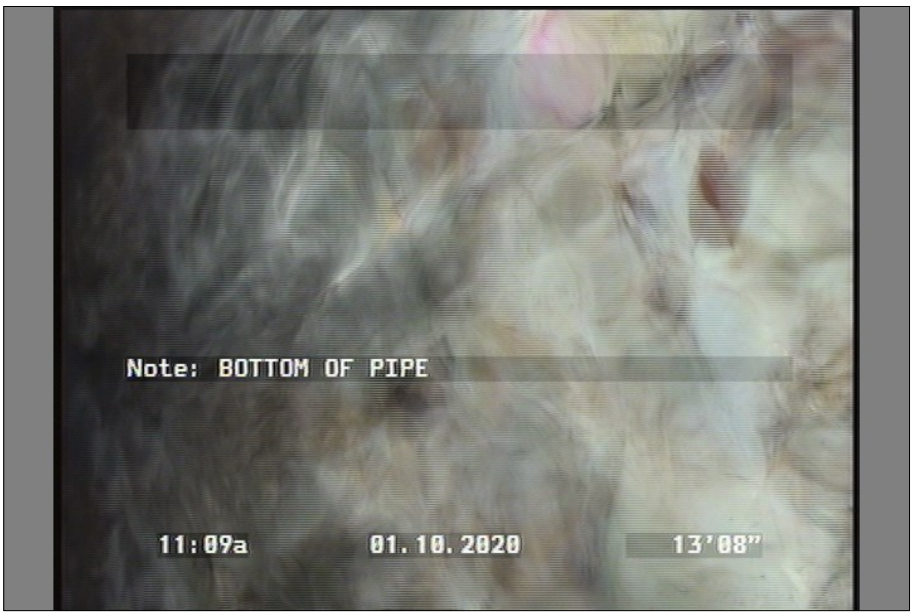

Photo: VALVE F8-009-NORTH-D-13.6504-110749.JPG
Note:

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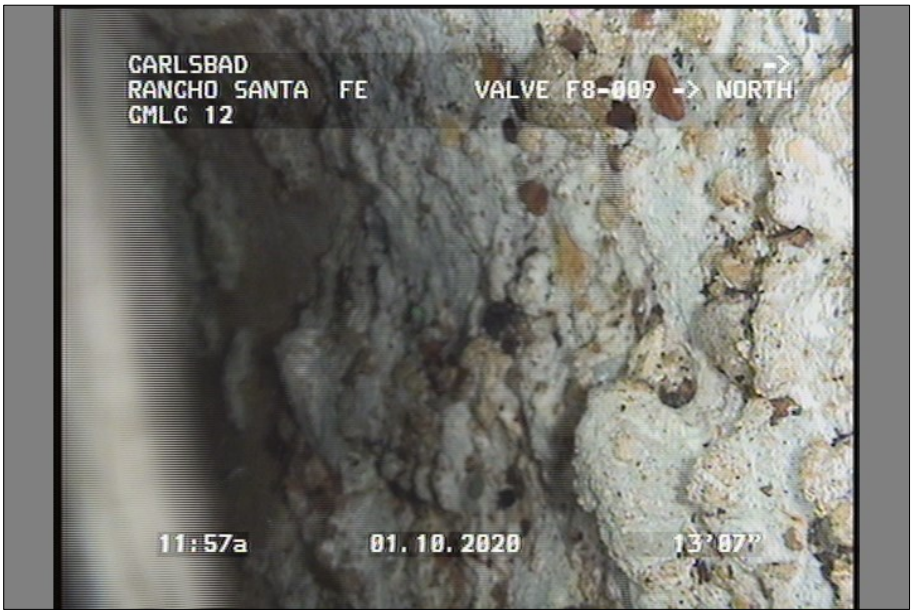

Photo: VALVE F8-009-NORTH-D-13.6504-115533.JPG
Note:

Photo: VALVE F8-009-NORTH-D-13.9606-110847.JPG
Service

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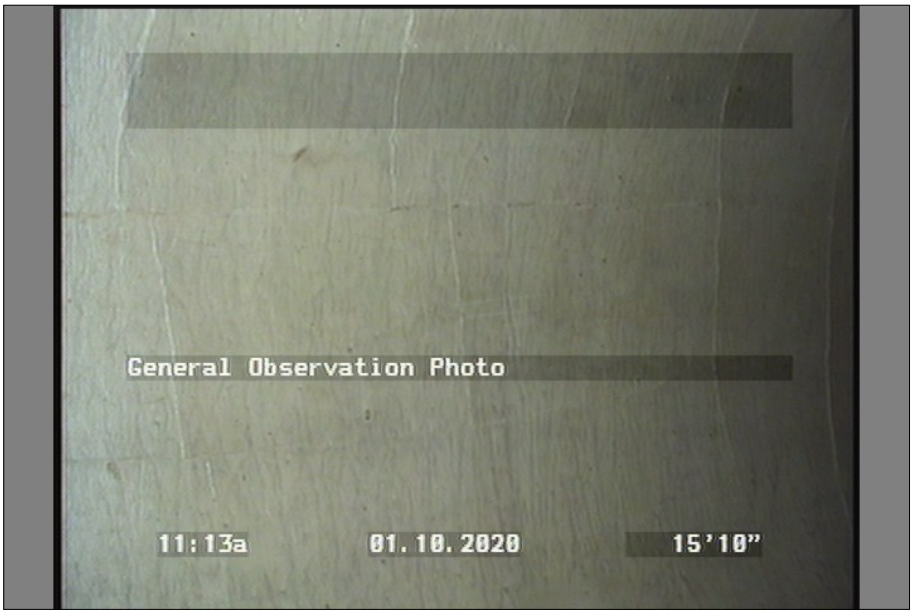

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General Observation Photo

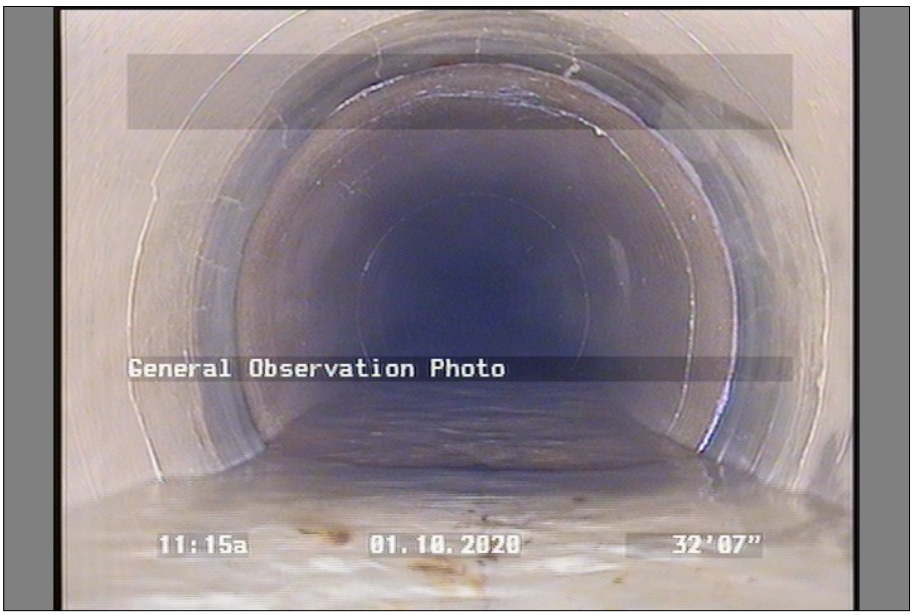

Photo: VALVE F8-009-NORTH-D-32.5748-111337.JPG
General Observation Photo

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Photo: VALVE F8-009-NORTH-D-34.2294-111358.JPG
General Observation Photo

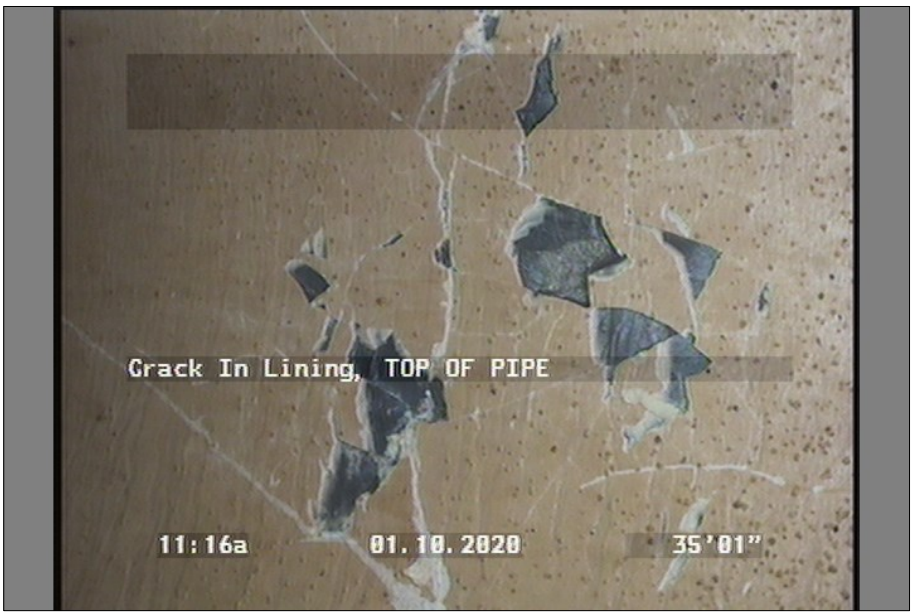

Photo: VALVE F8-009-NORTH-D-35.0567-111451.JPG
Crack In Lining

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CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

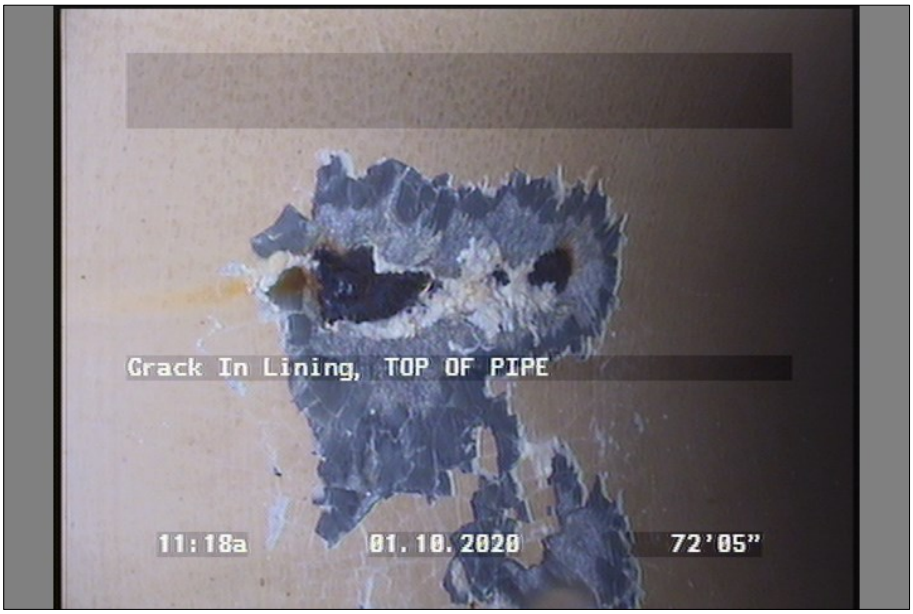

Photo: VALVE F8-009-NORTH-D-72.3885-111709.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-72.3885-111720.JPG
Crack In Lining

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Photo: VALVE F8-009-NORTH-D-73.7328-111808.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-73.7328-111816.JPG
Crack In Lining

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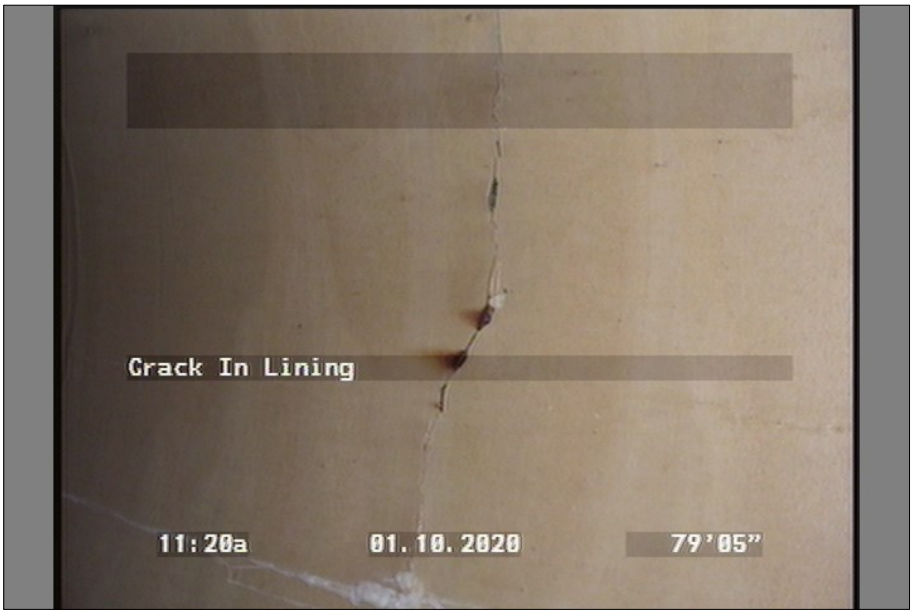

Photo: VALVE F8-009-NORTH-D-79.4205-111918.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-85.6252-112114.JPG
Note:

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Photo: VALVE F8-009-NORTH-D-85.6252-112122.JPG
Note:

Photo: VALVE F8-009-NORTH-D-91.6231-112211.JPG
Note:

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Photo: VALVE F8-009-NORTH-D-91.6231-112217.JPG
Note:

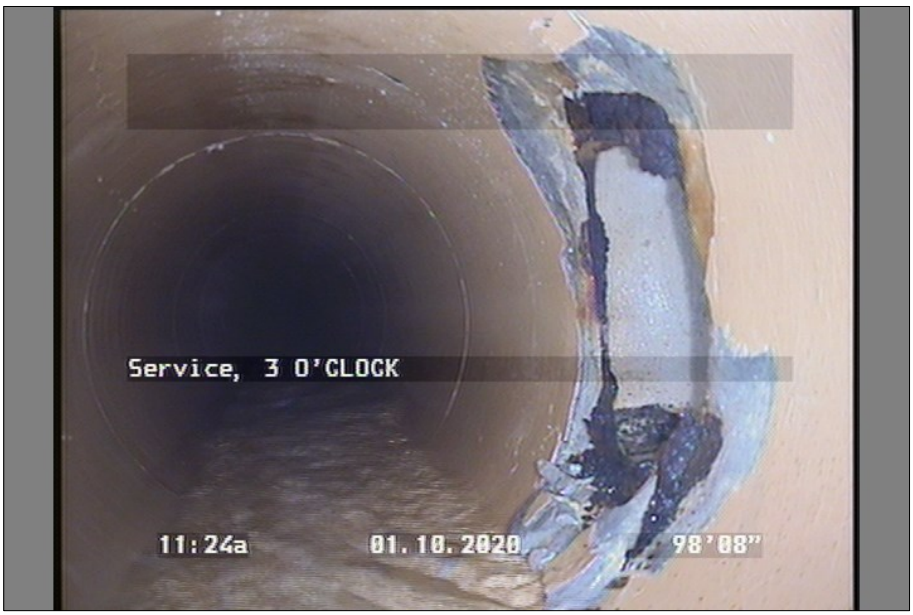

Photo: VALVE F8-009-NORTH-D-98.6551-112255.JPG
Service

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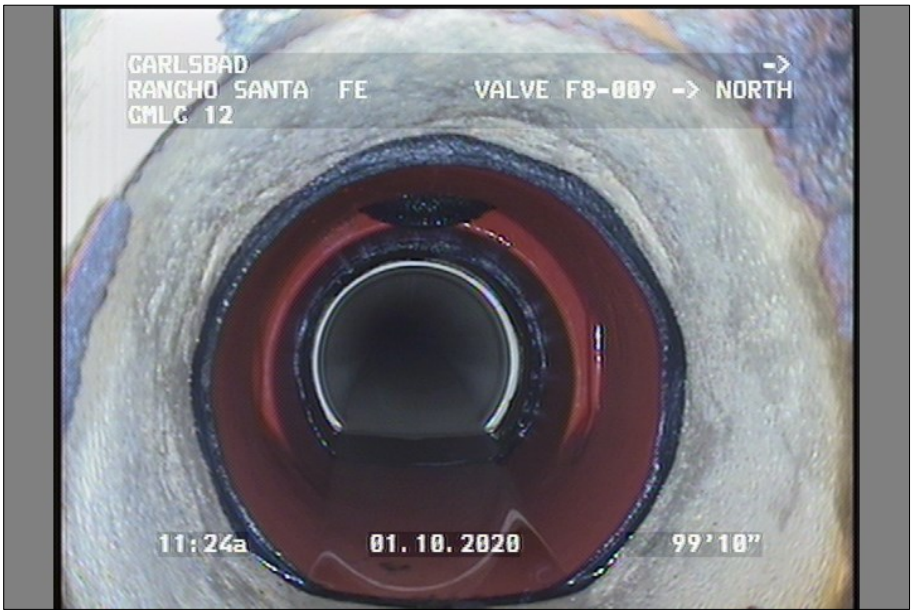

Photo: VALVE F8-009-NORTH-D-98.6551-112312.JPG
Service

Photo: VALVE F8-009-NORTH-D-102.4814-112341.JPG
Crack In Lining

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CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-151.2919-112637.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-151.2919-112648.JPG
Crack In Lining

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City :	Street :	Date :	Section # :	Section name :
CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-153.1533-112729.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-153.1533-112744.JPG
Crack In Lining

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CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-166.2866-112841.JPG
Note:

Photo: VALVE F8-009-NORTH-D-166.2866-112846.JPG
Note:

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City :	Street :	Date :	Section # :	Section name :
CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-168.5617-112914.JPG
Note:

Photo: VALVE F8-009-NORTH-D-192.5533-113009.JPG
Crack In Lining

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City :	Street :	Date :	Section # :	Section name :
CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-192.5533-113020.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-289.6572-113345.JPG
Note:

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CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

Photo: VALVE F8-009-NORTH-D-310.8567-113430.JPG
Crack In Lining

Photo: VALVE F8-009-NORTH-D-313.3386-120200.JPG
Note:

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City :	Street :	Date :	Section # :	Section name :
CARLSBAD	**RANCHO SANTA FE**	**1/10/2020**	**1**	

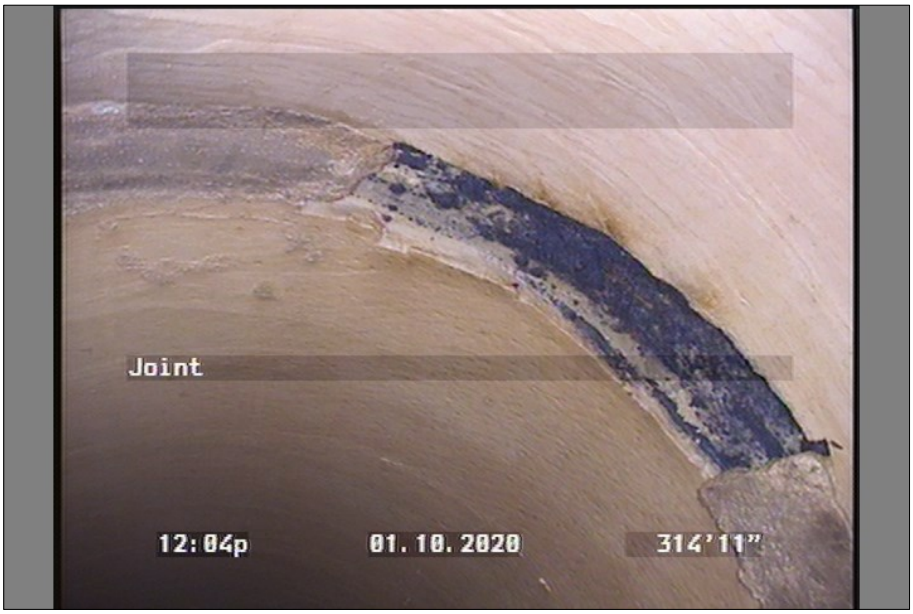

Photo: VALVE F8-009-NORTH-D-314.8898-120238.JPG
Joint

Appendix B. Defect Review and Repair Recommendations

No.	Defect Group	CCTV Odometer[1]	Video Observation[1]	PICA Pipe No.	PICA Location (ft)	PICA Defect Remaining Wall[2] [%]	PICA Clock Position[3]	PICA Estimated Defect Length [ft]	PICA Estimated Defect Length [In]	HDR Review Notes	HDR Repair Notes	Repair Cost - PICA and CCTV Defects and Anomalies	Repair Cost - PICA Defects Only	ECDA of PICA Identified Anomalies
1		12.82												
2		13.65	General observation Photo, Bottom of pipe							Appears to be concrete with aggregate on the bottom of the pipe.				
3	3	13.96	Service 12 oclock							Rusty hand hole at crown of pipe.				
4	3	15.82	General observation Photo							Minor cracks in lining				
5	3	32.57	General observation Photo							Minor cracks in lining				
6	3	34.23	General observation Photo							Missing mortar at joint, rust stains around joint				
7	3	34.23	Joint							Missing mortar at joint, rust visible in joint	Missing mortar and rust is identified in all joints that were CCTV inspected. Corrosion will eventually result in leaks at the joints. Consider monitoring these joints through leak detection or plan for rehabilitation or replacement.			
8	3	35.06	Crack in lining, Top of Pipe							Lining is chipping away from wall. Bare steel does not appear to be exposed. No rust visible.				
9	3	72.39	Crack in lining, Top of Pipe							Lining spalling and bare steel showing with rust.				
10	2	73.73	Crack in lining, Top of Pipe							Lining spalling at joint with significant rust	Repair and perform ECDA of removed pipe.	$60,000		
11	3	74.25	Joint							Missing mortar at joint, rust visible in joint				
12	3	79.42	Crack in lining							Minor crack in lining with rust				
13	3	85.63	Rust Visible							Minor crack in lining with rust				
14	3	91.62	Rust Visible							Minor crack in lining with rust				
15	3	98.66	Service 3 oclock							Missing mortar at joint, rust visible in joint				
16	3	102.48	Crack in lining, bottom of pipe							Minor cracking in lining				
17	3	113.13	Joint							Missing mortar at joint, rust visible in joint				
18	3	151.29	Crack in lining, Top of Pipe							Lining is chipping away from wall. Bare steel does not appear to be exposed. No rust visible.				
19	3	153.15	Joint							Missing mortar at joint, rust visible in joint				
20	2	153.15	Crack in lining, Top of Pipe							Lining spalling with significant rust	Repair and perform ECDA of removed pipe.	$60,000		
21	3	166.29	Rust Visible							Minor crack in lining with rust				

No.	Defect Group	CCTV Odometer[1]	Video Observation[1]	PICA Pipe No.	PICA Location (ft)	PICA Defect Remaining Wall[2] [%]	PICA Clock Position[3]	PICA Estimated Defect Length [ft]	PICA Estimated Defect Length [In]	HDR Review Notes	HDR Repair Notes	Repair Cost - PICA and CCTV Defects and Anomalies	Repair Cost - PICA Defects Only	ECDA of PICA Identified Anomalies
22	3	168.56	Rust Visible							Minor crack in lining with rust				
23	3	192.45	Joint							Missing mortar at joint, some rust visible in joint				
24	3	192.55	Crack in lining, Top of Pipe											
25	3	231.75	Joint							Missing mortar at joint, rust visible in joint				
26	3	271.04	Joint							Missing mortar at joint, rust visible in joint				
27	3	289.66	Rust Visible							Minor crack in lining with rust				
28	3	310.75	Joint							Lining spalling with rust stains visible				
29	3	310.86	Crack in Lining, CHIP											
30		311.99	Bend to right											
31	3	313.34	Chip in pipe							Missing mortar at joint, rust visible in joint				
32	2	314.89	Joint							Two large sections of mortar missing at bend joint, some rust visible	Repair and perform ECDA of removed pipe.	$60,000		
33		317.89	Camera Flip at Bend							45 degree bend				
34	3			0140	454.91	57%	5:30	0.15	1.8					
35	3			0170	536.73	69%	11:30	0.10	1.2					
36	3			0170	537.52	56%	11:30	0.11	1.3					
37	3			0170	560.66	33%	11:00	0.20	2.4					
38	3			0190	641.70	65%	11:30	0.25	3.0					
39	3			0200	682.45	77%	11:30	0.21	2.5					
40	3			0210	710.02	40%	6:30	0.09	1.1					
41	3			0210	723.06	69%	11:30	0.23	2.8					
42	3			0220	763.89	38%	12:00	0.18	2.2					
43	3			0230	804.93	34%	12:30	0.16	1.9					
44	3			0280	968.67	67%	2:30	0.10	1.2					
45	2			0320	1051.08	31%	5:30	0.12	1.4	Identified as Group 2 due to location proximity to a 21% RW defect.				

No.	Defect Group	CCTV Odometer[1]	Video Observation[1]	PICA Pipe No.	PICA Location (ft)	PICA Defect Remaining Wall[2] [%]	PICA Clock Position[3]	PICA Estimated Defect Length [ft]	PICA Estimated Defect Length [In]	HDR Review Notes	HDR Repair Notes	Repair Cost - PICA and CCTV Defects and Anomalies	Repair Cost - PICA Defects Only	ECDA of PICA Identified Anomalies
46	2			0320	1051.95	21%	5:00	0.19	2.3	This defect could be repaired or monitored. This defect is less likely to fail than other pipes with multiple through holes in close proximity. There are a number of defects with remaining wall thickness ranging from 21% to 56%. This location has a 31% remaining wall thickness defect in close proximity. The other defects are spread over the remainder of pipe 0320.	Repair or monitor.	$60,000	$60,000	
47	3			0320	1064.82	56%	4:00	0.20	2.4					
48	3			0320	1065.57	32%	5:30	0.20	2.4					
49	3			0320	1067.26	46%	5:00	0.13	1.6					
50	3			0320	1081.01	40%	4:30	0.17	2.0					
51	3			0330	1131.75	72%	11:30	0.20	2.4					
52	3			0340	1138.24	36%	5:00	0.11	1.3					
53	3			0340	1139.85	60%	7:00	0.18	2.2					
54	3			0340	1140.55	43%	6:00	0.17	2.0					
55	Anomaly			0340	1158.7 to 1172.5					PICA identified repeating signals at 4 locations along the crown of pipe that show characteristics similar to wall loss that are 4 feet from each other between 1158.7 ft and 1172.5 feet. However, the cause of this signal is unknown and could be related to a storm drain constructed nearby, cathodic protection or other issue.	Perform ECDA to verify issue and repair if needed.	$60,000		$13,500
56	3			0370	1248.34	47%	1:30	0.09	1.1					
57	2			**0370**	**1250.11**	**≤20%**	**4:30**	**0.17**	2.0	There are two potential through hole defects and another defect with 35% wall remaining within 8-inches of each other.	Repair. All defects on this pipe could be addressed with a buttstrap repair while the pipe is in service if defects are located precisely. Perform ECDA on excavated section.	$60,000	$60,000	

No.	Defect Group	CCTV Odometer[1]	Video Observation[1]	PICA Pipe No.	PICA Location (ft)	PICA Defect Remaining Wall[2] [%]	PICA Clock Position[3]	PICA Estimated Defect Length [ft]	PICA Estimated Defect Length [In]	HDR Review Notes	HDR Repair Notes	Repair Cost - PICA and CCTV Defects and Anomalies	Repair Cost - PICA Defects Only	ECDA of PICA Identified Anomalies
58	2			**0370**	**1250.31**	**≤20%**	**6:30**	**0.18**	2.2	See notes above for pipe 0370.	See notes above for pipe 0370.			
59	2			0370	1250.77	35%	4:30	0.09	1.1	See notes above for pipe 0370.	See notes above for pipe 0370.			
60	2			0380	1264.56	26%	5:00	0.07	0.8	Pipe 0380 has 3 potential through holes and significant wall loss at locations totaling approximately 20 feet along the pipe.	Replace 30-40 feet of pipe. Perform ECDA at existing pipe joints if exposed. Perform ECDA on excavated section.	$90,000	$90,000	
61	2			**0380**	**1264.75**	**≤20%**	**4:30**	**0.10**	1.2	See notes above for pipe 0380.	See notes above for pipe 0380.			
62	2			0380	1265.24	31%	5:00	0.09	1.1	See notes above for pipe 0380.	See notes above for pipe 0380.			
63	3			0380	1276.19	47%	5:30	0.11	1.3	See notes above for pipe 0380.	See notes above for pipe 0380.			
64	2			**0380**	**1276.66**	**≤20%**	**5:00**	**0.06**	0.7	See notes above for pipe 0380.	See notes above for pipe 0380.			
65	2			**0380**	**1277.00**	**≤20%**	**4:30**	**0.07**	0.8	See notes above for pipe 0380.	See notes above for pipe 0380.			
66	2			**0380**	**1277.13**	**≤20%**	**6:00**	**0.13**	1.6	See notes above for pipe 0380.	See notes above for pipe 0380.			
67	2			**0380**	**1277.29**	**≤20%**	**5:00**	**0.05**	0.6	See notes above for pipe 0380.	See notes above for pipe 0380.			
68	3			0380	1282.20	34%	7:30	0.18	2.2	See notes above for pipe 0380.	See notes above for pipe 0380.			
69	2			**0380**	**1283.71**	**≤20%**	**7:00**	**0.20**	2.4	See notes above for pipe 0380.	See notes above for pipe 0380.			
70	3			0380	1289.79	70%	5:30	0.08	1.0	See notes above for pipe 0380.	See notes above for pipe 0380.			
71	3			0380	1294.48	65%	12:30	0.07	0.8	See notes above for pipe 0380.	See notes above for pipe 0380.			
72	Anomaly			0390	1299.40					PICA indicated this location has significant wall loss, but may have been addressed with a previous pipe repair.	Consider ECDA to confirm finding and repair if needed.	$60,000		$13,500
73	3			0400	1375.14	63%	12:00	0.17	2.0					
											Subtotal	$510,000	$210,000	$27,000
											Additional Soft Costs (25%)	$127,500	$52,500	N/A
											Subtotal with Additional Soft Costs	$637,500	$262,500	$27,000
											Contingency (25%)	$159,375	$65,625	N/A
											Total Cost	**$796,875**	**$328,125**	**$27,000**

Notes:

1. Odometer reading and CCTV Visual Observations provided by Houston & Harris
2. Defects that measured <=20% remaining wall are highlighted in red
3. Clock positions are with a South to North perspective (9:00=West, 3:00=East