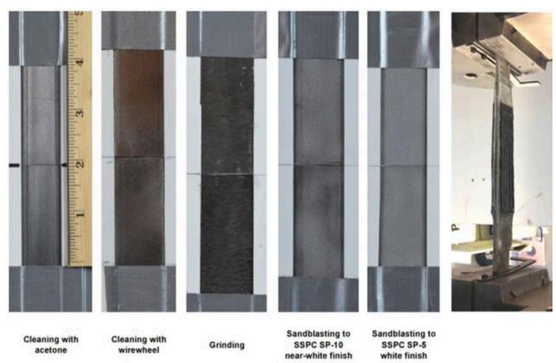
This experience is very relevant to the status of the CIPP industry and its potential way forward. ASTM F1216, which has been widely used for CIPP design, was first published in 1989, and ASTM F1743 was first published in 1996. ASTM F1216 has now been used without significant revision for three decades, although the range of applications of CIPP continues to evolve to higher pressure and larger diameter pipelines.

Major utilities like WSSC rightfully question the technical basis of CIPP application in cases that were not intended to be covered by the design approach of ASTM thirty years ago and advocate for research and development efforts for standardizing the design, material qualification, installation and QA/QC of CIPP, similar to the efforts undertaken for CFRP lining [11, 12].

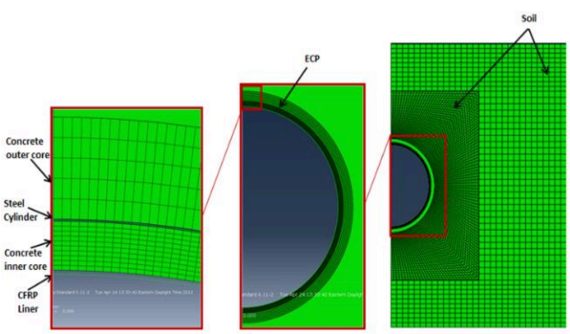
(a) Hydrostatic testing of CFRP-lined distressed pipe

(b) Three-edge bearing test

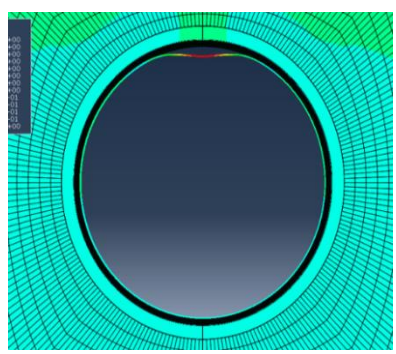
(c) Watertightness testing of CFRP laminate



(d) Shear-bond strength testing with varying surface preparation



(e) Finite element analysis of CFRP-lined buried pipe



(f) Buckling analysis of CFRP liner in buried pipe

Figure 4 – Examples of experimental testing and analyses performed for development of AWWA C305 [3].

CONCLUSIONS

The CIPP technology, which has been in use for over three decades and gained wide acceptance for lining of small diameter pipelines, is now being used for relatively high-pressure water pipelines in increasing diameters. However, it is often overlooked that ASTM F1216, which was developed three decades ago and is still commonly used for design, was initially intended for non-pressure applications (e.g., sanitary sewers, storm sewers, etc.) and therefore lacks important design considerations necessary for pressure pipes (e.g., longitudinal effects, combined effects of pressure and bending, etc.). Furthermore, CIPP liners are in many cases offered as Class IV fully-structural liners without demonstration of their long-term capability to safely resist all design loads, including vacuum, and without accounting for the current and future degraded condition of host pipe. These limitations are evident from WSSC's experience from pilot CIPP projects, two of which were presented in this paper. Available design guidance other than ASTM include a collection of information from multiple documents that were specifically developed for other applications using varying methodologies (e.g., LRFD, ASD), and their validity for CIPP design has not been verified. Based on a review of the state of the art and experience from pilot projects, development of an AWWA design standard specifically for CIPP is long overdue. As with modern design standards, CIPP standard should be based on LRFD approach that ensures uncertainties in both load and resistance are addressed to arrive at acceptable levels of reliability consistent with the consequence of failure of CIPP liners and with reliabilities used for other materials of construction. The development of AWWA C305 – CFRP Renewal and Strengthening of PCCP, which now benefits all stakeholders of CFRP lining, presents a relevant example. Considering the level of research and development necessary as evident from this example, establishing consensus and commitment among CIPP stakeholders to develop a CIPP design standard should not be further delayed.

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Dallas Water Utilities Uses Sliplining to Rehabilitate Aging 24-Inch Water Transmission Main

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ABSTRACT

Following the evaluation of a 24-in. transmission line, downsizing was selected to maintain service to an Emergency Interconnection, the only service point along this section of pipe, while improving water quality by reducing age. This paper discusses the benefits of rehabilitating waterlines using sliplining technology and fusible polyvinyl chloride pipe (FPVCP) in an urban setting.

INTRODUCTION

In 2016, the Town of Highland Park, Texas began a street improvements project on Preston Road. This project caused Dallas Water Utilities (DWU), the wholesale provider to the Town, to evaluate options for the 5,100 linear feet of 24-inch water transmission main located under the project limits. Due to water quality issues associated with age, the decommissioning and removal from service of the existing transmission line, originally installed in 1920, was evaluated during project development. Full replacement and rehabilitation options were also considered. A consideration during the evaluation of alternatives was the poor condition of the 100-year old pipe.

The Town of Highland Park is an affluent community, surrounded by the City of Dallas. Preston Road is the major North-South thoroughfare through the Town. It has consistent heavy traffic flows, is bordered by large estates, and provides access to Highland Park Village, an upscale shopping plaza and National Historic Landmark.

Because DWU was notified of the Preston Road project after the Town of Highland Park had contracted with another engineering firm to complete the design, the water transmission main project lagged the street improvements project. By the time Pacheco Koch Consulting Engineers, Inc., DWU's consultant, had completed the modeling effort and the preliminary design report, the southern portion of Preston Road had been resurfaced, while the northern portion awaited reconstruction.

STUDY

To evaluate the various alternatives under consideration for the water transmission main, modeling of the system was utilized. For the modeling effort, DWU provided a copy of their current H_2OMap hydraulic model, which was developed as part of the 2011 Distribution System Hydraulic Model Update. The hydraulic model included 2009 Summer Day and 2009 Winter Day Extended Period Simulation (EPS) scenarios. For the study to evaluate system performance, the Summer Day scenario was used, as higher demand conditions typically result in greater system stress observed in the distribution system. Additionally, development near the project location was assumed to be near buildout or fully developed; therefore, no significant changes in demand patterns were projected in the future. Table 1 – System Demands below summarizes the Summer Day Demands allocated to the model for the Central Plane, which includes the Town of Highland Park, and the entire system.

Table 1 – System Demands

Demands	Summer Day Average Demand (MGD)	Summer Day Peak Hour Demand (MGD)
Central Low Only	260	320
System Wide Total	557	678

Modeling Scenario 1: Existing Conditions

Under Scenario 1, the hydraulic model was run under the demand conditions listed in Table 1 with the 24-inch main in Preston Road in service to determine the base line or current operation conditions. Figure 1 – Existing Conditions illustrates the current Summer Day system performance (minimum hour pressure and maximum pipeline velocities) under the stated conditions.

Modeling Scenario 2: Main Abandoned

Under Scenario 2, the hydraulic model was run under the demand conditions listed in Table 1 with the 24-inch main in Preston Road abandoned. Figure 2 – Main Abandoned illustrates the current Summer Day system performance (minimum hour pressure and maximum pipeline velocities) under the stated conditions.

Results

A review of Figures 1 and 2 reveals there is only a slight difference when comparing system performance with the 24-inch main in service and the 24-inch main out of service. There are a select number of pipes with minor velocity changes (less than a 2-fps change in velocity) and there are negligible changes in system pressure (less than 1-psi change in pressure). The parallel 36-inch transmission main located just east of Preston Road (in Bishop Boulevard / Abbott Avenue), provides DWU significant north-south transmission capacity in the area even with the 24-inch main removed from service.

Although the DWU system performance was not impacted by the abandonment of the 24-inch transmission main, the Town of Highland Park desired to maintain service to its Emergency Interconnection. Ultimately, the decision was made to reduce the size of the main from 24-inches to 12-inches to match the piping at the Interconnection. This would improve the water quality by reducing the water volume and age.

DESIGN

Due to the high-profile project location, consistent heavy traffic flow, and affluent residential and business populations, it was established that a trenchless methodology would be the best option to avoid extensive disturbance to the area. With consideration to the clay filled soil in the area, sliplining was determined as the best rehabilitation solution. The existing 24-inch main would provide a suitable casing host pipe, allow for the sliplining process to be streamlined, and provide an additional barrier of protection from traffic loading above.

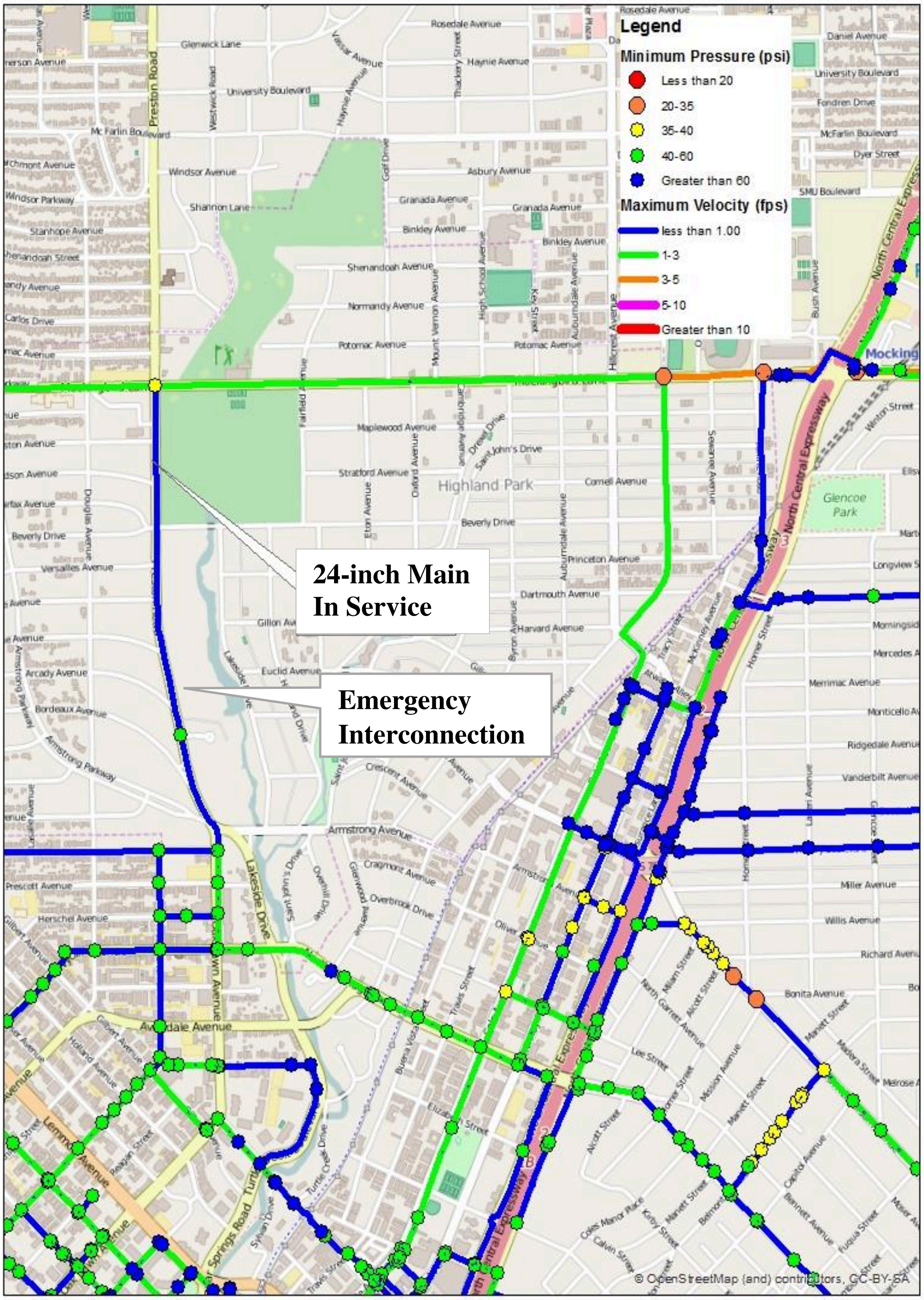

Figure 1 - Existing Conditions

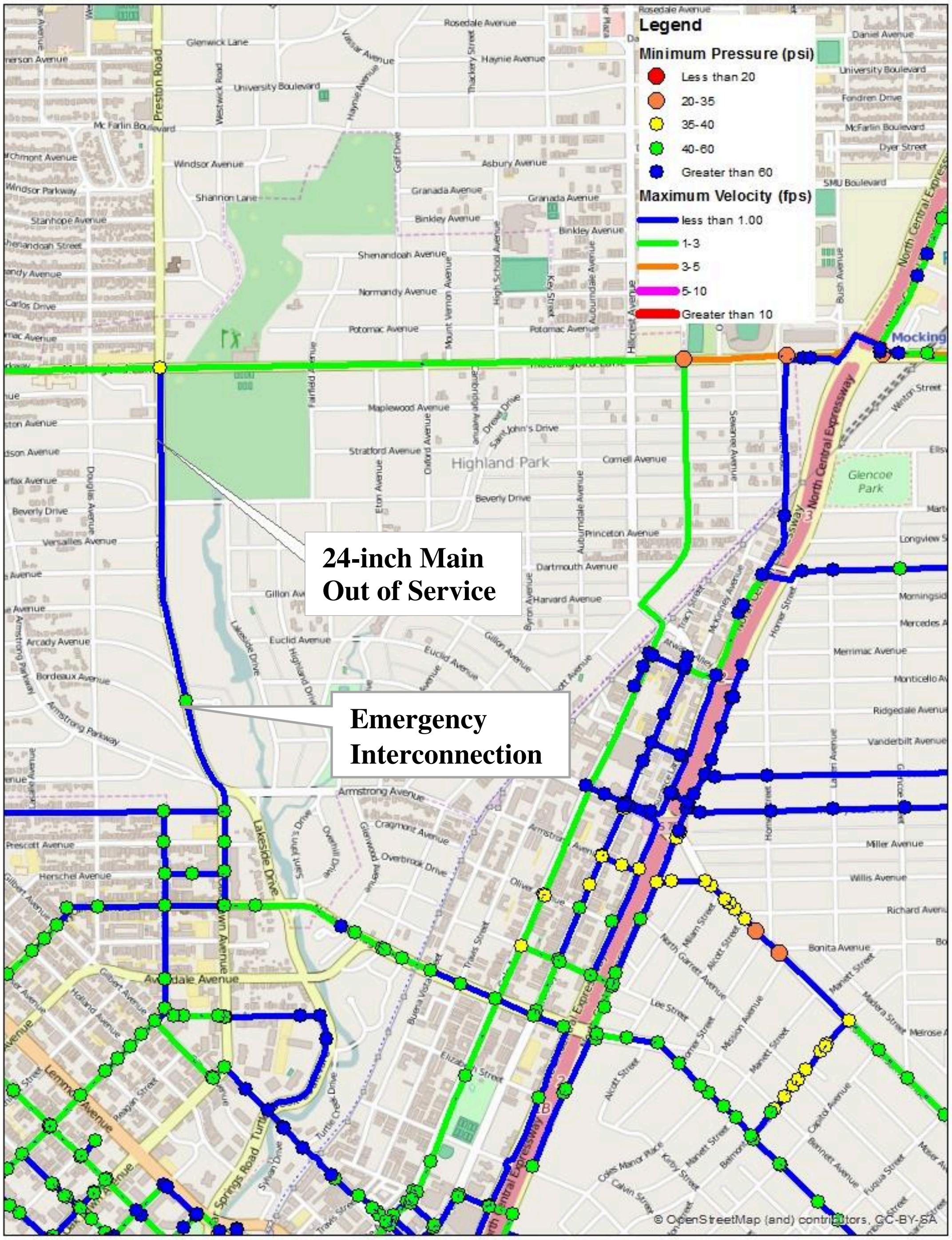

Figure 2 – Main Abandoned

This method also allowed for minimum disruption to existing utilities. A storm sewer network of pipes parallels and crosses Preston Road. This includes inlets and manholes within the right-of-way. In addition, telephone conduits are located on both the east and west sides of Preston Road that run the entire length of the project. Buried telephone cable is also located within the project area. Gas lines traverse the pavement in both north-to-south and east-to-west directions. Electrical service is underground and runs along the length of the road.

Since as-built drawings for the 24-inch water transmission main were not available due to the age of the installation, ground penetrating radar was used to locate the main horizontally and vertically, and to establish the location and dimension of curves along the main. The results from this investigation, performed by Survey and Mapping, LLC (SAM), are shown in Figure 3 – Ground Penetrating Radar.

The determination of the curvatures of installation was particularly critical in guiding the selection of pipe material. The maximum deflection angles of pipe joint are typically restricted by DWU to 75 percent of the manufacturer's recommendation. In addition, the maximum allowable pull-in force and maximum straight pull length were compared. The advantages and disadvantages of each pipe material were also evaluated. Table 2 – Evaluation of Pipe Materials contains the information considered during the selection of pipe material.

Fusible Polyvinyl Chloride Pipe (FPVCP) was sole sourced as the pipe product for the project. Its jointless, gasket-less, fully restrained nature provided the benefits of a fused monolithic piping system as well as the traditional preference for Polyvinyl Chloride Pipe (PVCP) in water systems due to the material's inherent resistance to corrosion and hydrocarbon contamination. In addition, its curve radius would allow the pipe to be safely pulled through the existing vertical curves, while its uniform cross section would allow the pipe to rest on the invert of the host pipe and be fully supported along its length. The use of standard waterworks appurtenances was an added benefit.

BIDDING

In mid-April 2018, the project to rehabilitate the 24-inch transmission main was bid simultaneously with the project to reconstruct Preston Road. In order to allocate costs appropriately, separate bid forms were included in the bidding documents. Seven bids were received on April 30, 2018. At $4,197,437.88, the low bidder for the combined projects was Ragle, Inc. This amount included $1,048,200.00 for the downsizing of the 24-inch water main by North Texas Contracting, Inc., which was 63 percent of the engineer's $1,669,374.00 estimate.

CONSTRUCTION

Construction of the Preston Road Project was started in 2018. The construction required the closure of one north-bound lane of traffic, adjacent to the east-side curb line, for the fusion, insertion and pulling processes. The entry and exit pits were installed at approximately 800-foot intervals. Although the pipe could be pulled over greater lengths, the interval length was limited to accommodate the cable lengths available for cleaning, CCTV and sliplining.

DR 14, FPVCP, 12-inch diameter pipe was delivered in lengths of 45-feet and fused on-site by Underground Solutions, Inc (UGS). UGS provided a technician trained and certified in the fusion of PVC pipe to ensure the integrity of the joints. Each joint fusion performed was recorded and logged by an electronic monitoring device (data logger) connected to the fusion machine. The fusion data logging and joint report was generated by software developed specifically for the butt-fusion of FPVCP.

process. This included cleaning, pigging and inspection using CCTV. Since the emergency interconnection, the only service point along the main, could be fed from either the north or the south, temporary water service was not required. Instead, the emergency interconnection would be fed from the north, while construction was being performed south of the interconnection, and fed from the south while the construction was being performed north of the interconnection.

Table 2 – Evaluation of Pipe Materials

Pipe Material	Pipe Properties	Advantages	Disadvantages
HDPE AWWA C906 DR 7.3 (318psi) 28.28 lb./ft.	• 300 feet Min. Curve Radius[A] • 74,400 lbs. Max. Pull-in Force • 2,600 ft. Max. Straight Pull Length[B]	• Pipe fully supported along length of host pipe. • Smallest Min. Curve Radius	• Connections to HDPE pipe are not common to DWU (Requires transition fittings or fused-on fittings)
PVC AWWA C900 DR 14 (305 psi) 23.5 lb./ft.			
Fusible	• 375 feet Min. Curve Radius[A] • 101,600 lbs. Max. Pull-in Force • 4300 ft. Max. Straight Pull Length[B]	• Largest Max. Pull-in Force • Longest Max. Straight Pull Length • Connections to PVC pipe are common to DWU (Standard waterworks fittings are used to tap, connect, and change direction) • Pipe fully supported along length of host pipe.	
Restrained Joint	• 375 feet Min. Curve Radius[A] • 48,300 lbs. Max. Pull-in Force • 2055 ft. Max. Straight Pull Length[B]	• Connections to PVC pipe are common to DWU (Standard waterworks fittings are used to tap, connect, and change direction)	• Smallest Max. Pull-in Force • Shortest Max. Straight Pull Length • Pipe not fully supported along length of host pipe.

[A] Standard Technical Specifications for Water & Wastewater Construction, Dallas Water Utilities, City of Dallas, 2017
[B] Calculated using a coefficient of friction (COF) = 1.0. For sliplining application, the COF is typically 0.3 to 0.5.

Prior to construction, the existing 24-inch transmission main was prepared for the insertion
The installation was performed in seven pulls of approximately 800-feet. Prior to each pull, two 300 to 400-foot lengths of pipe were fused. The length was based on the available laydown length, which was limited by driveways to the adjacent properties. The fusion at each joint required approximately 45 minutes. Near the end of the insertion of the first length of pipe, the second length of pipe was fused to the first and the insertion process continued to completion. Each pull between manholes was completed in eight hours.

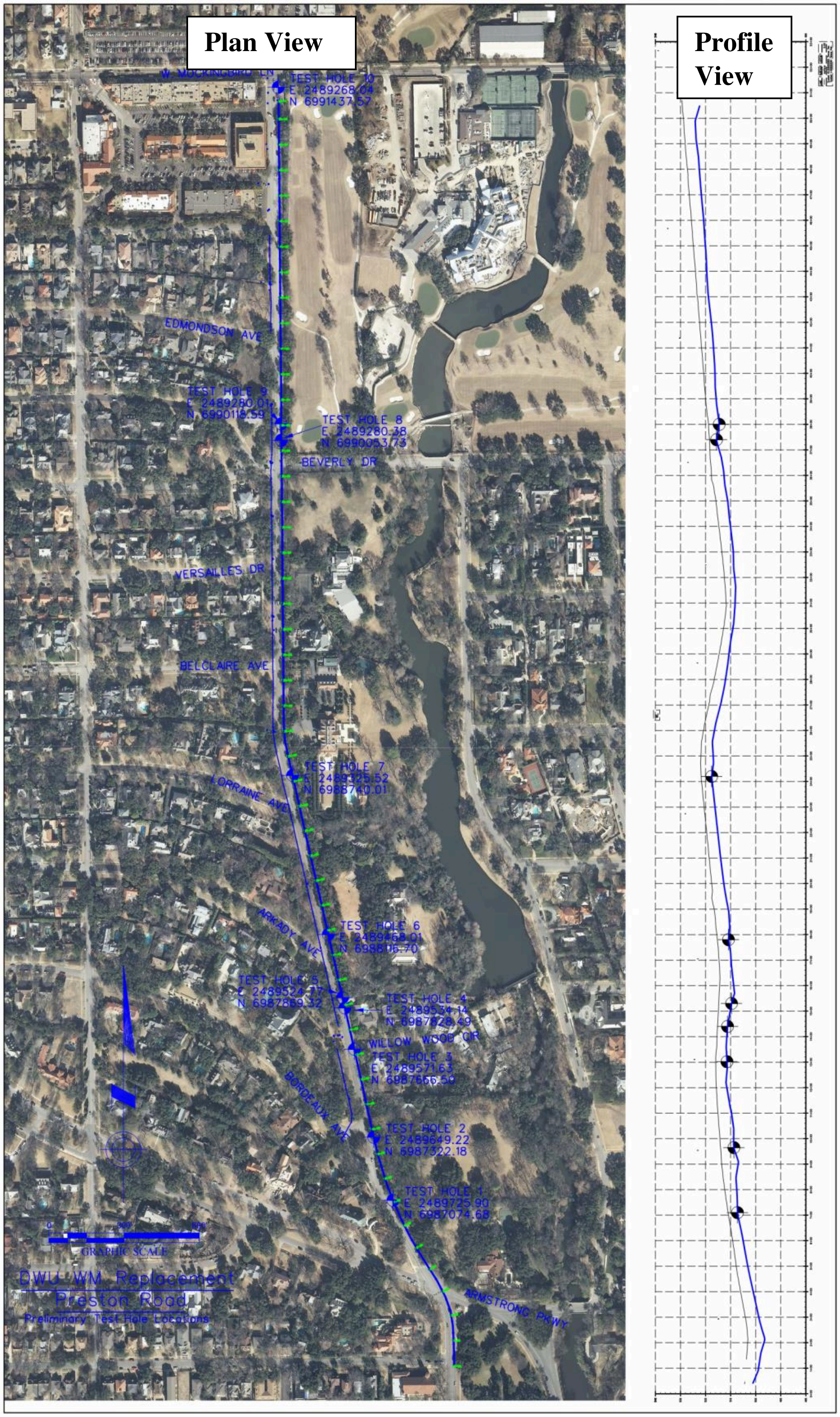

Figure 3 – Ground Penetrating Radar