Water Main Rehabilitation Alternatives

Ethan Heijn and Peter Larsen

The city of Fort Lauderdale’s water distribution system includes piping dating back to the 1940s. Most older piping has been rehabilitated or replaced. Some pipelines are in poor condition and the entire line may need to be replaced. Others are reasonably good condition, but valve accessibility, the number of connections, and traffic conditions along major thoroughfares or areas that are difficult to excavate for other reasons.

Some of the most effective approaches to rehabilitation and repair will be excavation and replacement. For others, a trenchless rehabilitation approach may be a feasible alternative. Rehabilitation alternatives were evaluated and recommendations were made for the following four water main projects:

Pipeline 1—Approximately 120 linear feet of 10-inch main along Las Olas Boulevard, including an aerial crossing supported beneath a heavily traveled traffic bridge over a tidal canal. This pipeline has been repaired multiple times with clamps and is in poor condition overall. Alternatives evaluated were rehabilitation, replacement, and alternate routes.

Pipeline 2—Approximately 3,700 lf of 16-inch main underlying a heavily traveled traffic route along North Andrews Avenue near the Boulevard, including an aerial crossing over a tidal canal. The cast-iron pipeline was originally 12-inch and 3,200 lf of 16-inch main underlying a heavily traveled roadway, Broward Boulevard, including an aerial crossing over a tidal canal. The cast-iron pipeline was originally 12-inch and

Pipeline 3—Approximately 5,900 lf of 12-inch main underlying a heavily traveled traffic route along South Andrews Avenue near the city center. This cast-iron line is in poor overall condition and has been repaired multiple times in the past; moreover, the line requires up to six inches, and therefore only alternatives capable of installing an 18-inch or 24-inch diameter main are evaluated. Alternatives evaluated were rehabilitation, replacement, and alternate routes.

Pipeline 4—Approximately 5,900 lf of 12-inch and 3,200 lf of 16-inch main underlying large commercial and industrial areas in which to perform construction work.

Trenchless Technologies For Rehabilitation

Trenchless technologies for water main rehabilitation are methods currently utilized to rehabilitate an existing manufactured liner pipe within the host main and in-situ spray application of a liner material.

Sliplining

Sliplining involves removing a portion of the existing water main and installing a new liner pipe into the existing main. While several types of thermostatic pipes have been used, HDPE is the most common. One drawback to sliplining is that the host main must be exposed at the conduit line for the iron pipe, oxidation of the pipe wall reduces internal deterioration of the main structural integrity or semi-structural water main rehabilitation and internal corrosion.

Spray Applied Lining Systems

Spray Applied Lining Systems were developed as a cost-effective alternative for rehabilitation water mains and has been spray-applied cement mortar lining, although recently a lining system designed as a membrane has been senting a competitive alternative. Both systems employ a rotating spray nozzle mounted on a skid or truck and centered within the pipeline. The pipe is then pulled through the host main by the host main. The ends of the water main are capped, after which the seal is positioned to fit tightly within the host pipe.

Cured-In-Place Systems

The most commonly used cured-in-place (CIP) lining systems employ either a non-woven felt bag or a woven polyester fiber bag, impregnated with cement. The impregnation is done using a rotating spray nozzle to the wall of an iron pipe, oxidation of the pipe wall ceases. Deterioration of the pipe wall ceases because, as the water passes through the porous cement mortar, it becomes alkaline and a chemical inhibitor against oxidation forms. This change in pH reduces internal deterioration of the main and eliminates or reduces the need to flush the replacement pipe. The addition of larger mains that allow the necessary access, a semi-structural capability can be obtained by installing a wire mesh within the liner. The addition of larger mains that require a complete cleaned and disinfected water main. All line valves must have their bonnets removed to clean the cement mortar from the valve interior.

Internal Joint Seals

Internal joint seals make the inside surfaces of leaking pipe joints watertight. The seal is flexible and designed to stick to the area on either side of the joint pared, after which the seal is positioned to span the gap and kept in place by stainless steel bands. The seal’s flexibility allows a bottle-tight seal around the entire pipe joint, ensuring that water cannot enter the water supply system. Internal joint seals are made of ethylene propylene diene monomer (EPDM) rubber. At the time of this study, the tech- nique had generally been applied only to larger pipes that allowed worker access, but recent robotic methods are on the horizon. Past page

The Water Main Rehabilitation Association (AWWA) has published a book, *A Wrench on the Main: Downfall of the Downman Era – Reinvigorating Water Infrastructure* (AWWA, 2001). This publication addressed the nation’s water infrastructure and the need to begin the rehabilitation and replacement of many of the older piping systems in the ground. The study concluded that by the year 2030, the average utility in the study will have to spend nearly four times more on pipe rehabilitation than it spends today, that needs would be driven more by the aging of buried infrastructure rather than by lack of maintenance or poor management, and that infrastructure rehabilitation would be most critical in inner-city cores where piping systems are oldest.

Older inner-city areas are the most densely developed areas and the most sensitive areas in which to perform construction work. The subsurface may include numerous existing utilities; abandoned pipes, rail and trolley tracks, multiple layers of paving, old foundations; piers; and other obstacles not shown on the plans or maps. On the surface, work may be complicated by narrow alleys, multiple buildings, traffic, and public activity. For these and other reasons, utilities are increasingly turning to trenchless methods for this work.

Increasing Use of Trenchless Methods for Water Main Repairs

The American Water Works Association (AWWA) reports that trenchless rehabilitation methods have increased in acceptance among public utilities. A Wrench on the Main: Downfall of the Downman Era – Reinvigorating Water Infrastructure (AWWA, 2001). This publication addressed the nation’s water infrastructure and the need to begin the rehabilitation and replacement of many of the older piping systems in the ground. The study concluded that by the year 2030, the average utility in the study will have to spend nearly four times more on pipe rehabilitation than it spends today, that needs would be driven more by the aging of buried infrastructure rather than by lack of maintenance or poor management, and that infrastructure rehabilitation would be most critical in inner-city cores where piping systems are oldest.

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All bursting systems require openings in the existing pipe long enough to accommodate the bursting tool and to provide space for new pipe to be fed into the main. All valves, fittings, and service connections must be removed in advance to avoid damage. Any repair clamps on the existing pipe should also be identified and may require advance removal.

An important consideration, especially with the pneumatic tool, is the impact on other structures or utilities. The bursting tool will create a pressure zone, the size of which will depend on the type of soil, the size of the host pipe, and the degree of up-sizing for the new pipe. There may also be vibration impacts.

For most operations, the potential for damage to utilities will become significant only at very close ranges. In the case of a utility crossing, the damage can be prevented by exposing the crossing and removing the soil between the utilities. For close parallel utilities, open cutting may be needed if the existing main is to be upsized.

### Horizontal Directional Drilling

Horizontal directional drilling (HDD) consists of several installation stages. First, a pilot bore is made with a suitable-sized drilling rig. The bore is steered to create an initial hole at the required line and grade. Successive reamers are then pulled back to enlarge the bore diameter to the desired size. During the last stage of reaming, the service pipe is pulled back into the bore.

This method is frequently employed when an open-cut excavation is unsuitable, such as at a railway crossing. Most water mains installed by this method are continuously welded PE pipe, although steel, ductile iron, and PVC have also been used. Since HDPE pipe is subject to contraction and expansion, restraint mechanisms should be considered in the design stage.

### Micro-Tunneling

While micro-tunneling is normally used for very deep, usually new installations, applications have included rerouting existing water mains. Micro-tunneling uses a remotely controlled boring machine combined with the pipe jacking technique to install pipelines. Experts should be engaged for any application of this technology. Like horizontal directional drilling and pipe bursting techniques, there is limited quality control of pipe bedding and side fill support.

While microtunneling is technically feasible for replacement, it was not considered for the pipelines discussed in this article because of the specialized nature of microtunneling applications.

### Design Considerations

The decision on which rehabilitation measure to use depends primarily on hydraulic adequacy, structural conditions, and surface conditions.

- Hydraulic adequacy refers to the capacity of the existing pipe to accommodate present or future flow requirements. A pipe that is undersized must be upsized or paralleled, indicating the use of either open-cut methods, pipe bursting, or HDD.
- Structural condition assessment will ideally include field data from test coupons, flow tests, or other field inspections which can identify problem pipe segments prior to failure. Other indicators may be a history of main breaks or customer complaints of low flow volumes, low pressures, colored water outbreaks, or taste and odor problems. A cast-iron main that is structurally sound and hydraulically adequate but has contributed to colored water complaints can be lined with a non-structural liner, but if the main is in poor physical condition, a structural liner or replacement method is warranted.
- Surface conditions may influence a decision to use a trenchless method. Where the main is easily accessible and away from the public, such as in an easement or on the shoulder of a road, conventional open cut will generally be preferred. In congested urban areas or sensitive environmental areas such as wetlands, trenchless methods may be preferred.

Table 1 provides general guidance concerning the suitability of the alternative technologies to address a typical range of water main problems.

It is important to note that these "trenchless" technologies are not "no-dig" technologies. Each method requires excavation pits for access to the main. Sliplining and pipe bursting generally require larger pits to provide enough space for inserting the new liner pipe. These pits may be on the order of 4 feet wide by 15 to 20 feet long, depending on the methods and materials used. Spray-applied lining systems and cured-in-place lining systems will require smaller pits for equivalent access and retrieval, generally on the order of 4 feet wide by 6 to 10 feet long.

All methods will require pits for access to valves, elbows, tees, and service connections. Generally, these pits need be no larger than necessary to gain access to the fitting and can usually be limited to about 4 feet square (pit dimensions assume mains have been installed at the minimum required depths). Cost estimates, therefore, must include the number, size and location of access pits as well as surface restoration.

Other critical items to consider in technology selection include the size of the contract, local availability of the technology, possible impacts of the water main material to be used (potential expansion/contraction Continued on page 33
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issues), and the density of water services on the water main.

With larger contracts, more options will be available for various technologies, since mobilization costs may be high for specialized equipment and personnel. Moreover, some regions may have little local presence of some of the newer technologies. This factor is linked to the contract size, since a larger contract may attract companies from other regions.

The quantity and density of water services, valves, and branch piping connected to the water main may play a large role in selecting alternative technologies, since these fittings will require excavation for preparation and reinstatement. If such fittings are numerous, then open-cut replacement is likely the most economical solution.

Another important consideration is whether the utility will provide temporary bypass piping to maintain water service during performance of the work. This can be time-consuming and expensive, and it can be a significant differentiator among alternative approaches.

Cost-related guidelines reflect only the actual construction work and do not include other community concerns. Using a different technology at a higher construction cost than the open-cut method may be in the best interests of the community when issues such as traffic, impacts on commercial and industrial customers, and environmental and safety concerns are considered.

Alternative Evaluation & Recommendations

Based on specific pipeline conditions, advantages and disadvantages of the various technologies, and design considerations, alternatives were evaluated and recommended for rehabilitation or replacement of each pipeline. Cost estimates were developed to compare feasible alternatives.

Pipeline 1 – 120 lf of 10-inch main including an aerial canal crossing

Required evaluation scenario for this project include rehabilitation, replacement, and upsizing using an alternate route. Upsizing was not identified as a necessary consideration.

Joint failure and/or localized corrosion causing leakage

Pipe bursting, HDD, open cut

Table 1: Suitability of the Technologies

<table>
<thead>
<tr>
<th>Water Main Problem</th>
<th>Potentially Suitable Technologies</th>
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<tbody>
<tr>
<td>Tubeacement in structurally sound pipe, causing poor water quality and flow restriction</td>
<td>Spray lining, CP lining, deformed/reformed lining</td>
</tr>
<tr>
<td>Joint failure and/or localized corrosion causing leakage</td>
<td>CP lining, joint seals</td>
</tr>
<tr>
<td>Extensive corrosion or graphitization, with loss of structural strength causing breaks and leaks</td>
<td>CP lining, deformed/reformed lining, slip lining, pipe bursting, HDD, open cut</td>
</tr>
<tr>
<td>Pipe diameter too small, causing flow restriction</td>
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Pipeline 1 – 120 lf of 10-inch main including an aerial canal crossing

Required evaluation scenario for this project include rehabilitation, replacement, and upsizing using an alternate route. Upsizing was not identified as a necessary consideration.

Given the poor overall condition, technically feasible alternatives for rehabilitation were limited to installation of a structural liner. Neither spray lining nor joint seals could not be considered for the same reason. With this technology, the possibility of hitting another utility is always a major concern and adds significantly to the cost in proportion to the contractor’s perceived level of risk. HDD was considered to have greater feasibility for a portion of this project, as noted later in this article.

The recommended alternative for this project was to install a 24-inch line using open-cut methods. Portions of the work would be conducted at night to minimize traffic disruptions. HDD could be considered

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for that portion of the line crossing the largest intersection, but since this crossing would be made at substantial depth to avoid other utilities, a hydraulic evaluation would be needed concerning the importance of re-establishing the branch connections and associated valves within the intersection.

Several factors place the open-cut method at an advantage for this project. The line is reportedly shallow, and installing an upsized line using this method adds relatively little in cost and essentially no additional risk. Regulators are familiar with this approach, making the permitting process potentially easier than might be the case with a less-familiar trenchless technology. The strong availability of local contractors for this method, moreover, should help the city obtain competitive pricing for such a project.

Another major advantage of this method over most trenchless methods would be the opportunity to complete the work without the time-consuming, expensive task of providing temporary water service to affected customers. The new line could be built in parallel, and only brief losses of service would be experienced—perhaps a one-night shift for cutting in each section of line and, on a subsequent occasion, a few hours of service when services are switched over to the new line. Any option that entailed internal work on the existing line (bursting or lining, for example) would result in a much longer loss of service than could be reasonably tolerated by the city’s customers without temporary water supply.

Another factor that encourages open cut on this line is the high total number of branch connections, services, hydrants, and valves, each of which would require excavation for rein-statement. The primary advantage of trenchless methods is, of course, the avoidance of digging, and on a long stretch of line with few or no fittings, this advantage can translate into both monetary savings and greatly reduced disruption. On the subject line, however, so much digging would be required for reinstatement—often within intersections at the point of greatest impact to traffic—that the potential advantage of a trenchless approach could not be realized.

It was recommended that this work be done, if possible, in coordination with the county’s repaving schedule and reported plans to redevelop properties along this pipeline. The possibility of a joint partnership agreement with the county would also be explored.

Pipeline 3 – 4,300 ft of 4-inch main underly-
ing a moderately busy traffic route.

Given the fact that this line requires upsizing, rehabilitation approaches did not apply. Pipe bursting and HDD were considered but not recommended for the same reasons given for Pipeline 2.

The recommended alternative for this project was to install an 8-inch line using open-cut methods. The factors placing open cut at an advantage for this project were the same as those described for Pipeline 2. Also, for Pipeline 3 the road is wide and traffic volume is moderate, so the prospect of lane closures is more acceptable. Excavation of some intersections during off-hours with appropriate traffic detours was recommended.

As with Pipeline 2, it was recommended that attempts be made to coordinate this work with the county’s repaving schedule and reported plans to redevelop properties along this pipeline. The possibility of a joint partnership agreement with the county would also be explored.

Pipeline 4 – 9,100 ft of main (12-inch and 16-
inch) underlying a very busy roadway.

Required evaluation scenarios for this project include rehabilitation, replacement, and upsizing of the 16-inch segment to 24 inches and the 12-inch segment to 18 inches. Technically feasible alternatives for rehabilitation and replacement were the same as those outlined for Pipeline 2 and were decided against for the same reasons.

The long-term recommendation for this project was to install an upsized line using open-cut methods. The factors placing open cut at an advantage for this project were the same as those described for Pipeline 2, with the added emphasis that blocks are relatively short and branch connections exist at nearly every intersection, a circumstance that would require extensive excavation in intersections even if trenchless methods were used. HDD or jack and bore methods would be needed, however, for a portion of the line under railroad tracks. Portions of the work would be conducted at night to minimize traffic disruptions.

The short-term recommendation was to take no action. The road surface is relatively new, and traffic is extremely heavy. The Florida Department of Transportation has stated that a five-year moratorium exists on non-emergency work that would require cutting into the road surface. Any emergency repairs would be addressed as required, but otherwise, work would be postponed until it could be performed in conjunction with another significant infrastructure effort affecting that stretch of road.

It was seen as possible, given the generally good condition of the main as evidenced by a pipe coupon obtained from a tap of the pipeline, that the pipe itself could last a good deal longer, and that the joints, although susceptible to separating and developing leaks if disturbed, would cease to develop many problems since nearby construction work has been completed and the sources of disturbance have been greatly reduced.

The pipe coupon was collected in December 2003 and exhibited an average thickness of 13.91 mm, or about 0.55 inches. While the original thickness and pressure class of the pipe was not known, a Class B (86 pounds pressure) cast-iron pipe today would be manufactured with a wall thickness of 0.70 inches.

Conclusions

For three of the four pipelines that were evaluated, despite the technical feasibility of several trenchless methods, open-cut methods were recommended for two primary reasons. First, trenchless methods still require that numerous fittings for branch connections, services, hydrants, and valves on the lines be excavated for preparation and reinstatement, often in major intersections where the greatest traffic impacts would occur. Second, the open-cut method would allow the new line to be built in parallel and brought into service quickly, with only minor service interruptions to customers. This would avoid the costly and time-consuming necessity of providing temporary water supply, an advantage not offered by trenchless alternatives.

For the fourth pipeline, trenchless installation of a structural liner was recommended. In this case the major difference was that the stretch of pipeline requiring rehabilitation had no services or other fittings requiring excavation and could be valved off at each end during the rehabilitation without adversely impacting any customers.

References

5. International Society for Trenchless Technology, Trenchless Technology Guidelines, not dated