

SELECTION OF TECHNOLOGIES FOR THE REHABILITATION OR REPLACEMENT OF SECTIONS OF A WATER DISTRIBUTION SYSTEM

A BEST PRACTICE BY THE NATIONAL GUIDE
TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

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Municipal
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Selection of Technologies for the Rehabilitation or Replacement of Sections of a Water Distribution System

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FOREWORD

In spite of recent increases in public infrastructure investments, municipal infrastructure is decaying faster than it is being renewed. Factors such as low funding, population growth, tighter health and environmental requirements, poor quality control leading to inferior installation, inadequate inspection and maintenance, and lack of consistency and uniformity in design, construction and operation practices have impacted on municipal infrastructure. At the same time, an increased burden on infrastructure due to significant growth in some sectors tends to quicken the ageing process while increasing the social and monetary cost of service disruptions due to maintenance, repairs or replacement.

With the intention of facing these challenges and opportunities, the Federation of Canadian Municipalities (FCM) and the National Research Council (NRC) have joined forces to deliver the *National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices*. The Guide project, funded by the Infrastructure Canada program, NRC, and through in-kind contributions from public and private municipal infrastructure stakeholders, aims to provide a decision-making and investment planning tool as well as a compendium of technical best practices. It provides a road map to the best available knowledge and solutions for addressing infrastructure issues. It is also a focal point for the Canadian network of practitioners, researchers and municipal governments focused on infrastructure operations and maintenance.

The *National Guide to Sustainable Municipal Infrastructure* offers the opportunity to consolidate the vast body of existing knowledge and shape it into best practices that can be used by decision makers and technical personnel in the public and private sectors. It provides instruments to help municipalities identify needs, evaluate solutions, and plan long-term, sustainable strategies for improved infrastructure performance at the best available cost with the least environmental impact. The five initial target areas of the Guide are: potable water systems (production and distribution), storm and wastewater systems (collection, treatment, disposal), municipal roads and sidewalks, environmental protocols and decision making and investment planning.

Part A of the *National Guide to Sustainable Municipal Infrastructure* focuses on decision-making and investment planning issues related to municipal infrastructure. Part B is a compendium of technical best practices and is qualitatively distinct from Part A. Among the most significant of its distinctions is the group of practitioners for which it is intended. Part A, or the decision making and investment planning component of the Guide, is intended to support the practices and efforts of elected officials and senior administrative and management staff in municipalities throughout Canada.

It is expected that the Guide will expand and evolve over time. To focus on the most urgent knowledge needs of infrastructure planners and practitioners, the committees solicited and received recommendations, comments and suggestions from various stakeholder groups, which shaped the enclosed document.

Although the best practices are adapted, wherever possible, to reflect varying municipal needs, they remain guidelines based on the collective judgements of peer experts. Discretion must be exercised in applying these guidelines to account for specific local conditions (e.g. geographic location, municipality size, climatic condition).

For additional information or to provide comments and feedback, please visit the Guide at <www.infraguide.gc.ca> or contact the Guide team at infraguide@nrc.ca.

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EXECUTIVE SUMMARY

This best practice focusses on the selection of available technologies for the replacement or rehabilitation of water mains and associated appurtenances. The operations, maintenance, and management of water distribution systems can be complex, and rehabilitating or replacing existing water mains to meet a community's needs is an ongoing occurrence across Canada.

With much of the water infrastructure buried, it is difficult to prioritize maintenance activities while continuously operating a reliable system that meets the needs of customers and the community. This best practice provides municipalities with a method for selecting the appropriate water main rehabilitation or replacement technology based on social, economic, and environmental factors, and on current best practices in the industry.

The process outlined in this best practice assumes the municipality has already determined that a section of water main requires remedial action. That determination should have been based on a prioritization scheme that is in the best interests of the entire community. Understanding the overall operations of the water distribution system is critical in this regard, and a municipality should have as much background information on its infrastructure as possible to help prioritize decisions. This includes the following:

- Make sure the appropriate level of operations and maintenance activities is taking place.
- Collect, store, and analyze all data gathered on the water infrastructure, including water quality issues, to allow managers to make knowledgeable operations, maintenance, and rehabilitation/replacement decisions.
- Have an understanding of the type and condition of the soils adjacent to the water mains, the water table and any environmental conditions that may affect the infrastructure.
- Identify and understand any other buried or surface infrastructure that could have an impact on the system.
- Consider all community concerns, including financial constraints, life cycle costing, social issues, local environmental issues, and co-ordination of other surface and buried infrastructure work.

Items that should be considered before selecting a rehabilitation or replacement technology for remedial action include:

- construction issues, such as safety, operability, cost, and efficiency;

- the size of the contract, as smaller contracts may preclude some alternatives due to the cost of mobilizing specialized equipment and personnel;
- the risk of undertaking (or not undertaking) the project, focussing on environmental and construction issues, and anything that may adversely affect the project's objective;
- local availability of the various technologies, as some are not yet available in parts of Canada;
- the depth of the water main, which may limit the technologies available to rehabilitate or replace that water main. (i.e., north of 60° latitude or systems in permafrost); and
- the density of water services, which may substantially increase the overall cost of construction of some of the newer technologies, if excavations are required to reconnect each water service.

This best practice provides a flow diagram for a municipality to follow in determining the technologies available for the rehabilitation or replacement of water mains in their specific situation. Use of this flow diagram assumes that a decision has already been made that remedial action is required. The flow diagram identifies the problems, addresses the possible causes of the problem, and provides two options (full replacement/structural rehabilitation or non-structural/semi-structural rehabilitation). The current available technologies are also identified and discussed.

By following the steps in this best practice, a municipality can feel confident it has considered all economic, social, environmental, and local issues in its decision process, and has done so in the best interests of the community.

1. GENERAL

1.1 INTRODUCTION

This best practice was initiated following a scan on prioritizing and choosing technologies for constructing and rehabilitating potable water linear systems, completed for the *National Guide to Sustainable Municipal Infrastructure*. The Executive Summary of this scan, referred to as Scan SWW-1 (PW), can be viewed on the National Guide's Web site <www.infraguide.gc.ca>. Based on the data collected from this scan, it was recommended that a best practice be developed to guide municipalities on how to select an appropriate technology for the rehabilitation or replacement of sections and appurtenances of a water distribution system that require remedial action.

1.2 FRAMEWORK

This best practice provides municipalities with a guideline for selecting the best appropriate technologies to rehabilitate or replace sections of their water distribution system based on current practices and on local issues and conditions. By selecting appropriate technologies, municipalities can then make capital improvement, operations, and maintenance decisions in the best interests of the community they serve and their water customers.

It should be noted that cathodic protection (CP) of water mains and appurtenances is excluded from this best practice, because it has no rehabilitative component. Rather, it is considered a maintenance technique that delays the corrosion process in aggressive soils and thus prolongs the useful life of the water main asset.

Although water services are mentioned, it should be noted that rehabilitation of water service lines is excluded from this best practice. It should be noted that the rehabilitation/replacement of water services can have an impact on the selection of an appropriate water main rehabilitation or replacement technology.

1.2.1 LINKS TO CURRENT WATER INDUSTRY BEST PRACTICES IN WATER MAIN REHABILITATION AND REPLACEMENT

Two leading organizations aid municipalities, water utilities, consultants, contractors, individuals, and other organizations in the pursuit of best practices with regards to water main rehabilitation and replacement. For those municipalities that are involved in research and in helping develop strategies in the rehabilitation and replacement of water mains, it is recommended that they get involved with the American Water Works Association (AWWA) and the North American Society for Trenchless Technologies (NASTT). This, in turn, will allow their knowledge and expertise to be disseminated by these organizations for the betterment of municipalities and potable water suppliers everywhere. These organizations can be monitored or contacted via their Web sites: <www.awwa.org> and <www.nastt.org>.

It should be noted that there are many other organizations involved in infrastructure rehabilitation, including the Water Environment Federation (WEF), the American Society of Civil Engineers (ASCE), the Water Resource center (WRc), and the Drinking Water Inspectorate in the United Kingdom, as well as academia. All organizations have a role to play in the pursuit of continuous improvement initiatives for water main replacement and rehabilitation. A recent research report published in June 2002 by the National Research Council, Institute for Research in Construction (report #101), “Construction and Rehabilitation Costs for Buried Pipe with a Focus on Trenchless Technologies”, highlighted recent costs (1993–2000) for trenchless technologies.

The National Guide’s Potable Water Technical Committee will continue to monitor these organizations and others to make any updates or changes to this best practice.

1.2.2 NEW AND EMERGING TECHNOLOGIES

In utilizing this best practice, the user must be aware that new technologies and new materials are emerging every year. The existing technologies are continuously changing and being improved upon also. This best practice thus identifies the proven technologies available at the time of writing.

1.3 GLOSSARY

The intent is to use standard terms that are recognized internationally, allowing municipalities to communicate among themselves in terms that have previously been defined. These particular definitions have been provided courtesy of NASTT (North American Society for Trenchless Technologies); a more detailed version can be found on its Web site <<http://www.nastt.org/glossary/j.html>>.

Boring — (1) The dislodging or displacement of spoil by a rotating auger or drill string to produce a hole called a bore. (2) An earth-drilling process used for installing conduits or pipelines. (3) Obtaining soil samples for evaluation and testing.

Butt fusion — A method of joining polyethylene pipe where two pipe ends are rapidly brought together under pressure to form a homogeneous bond.

Cathodic — A process by which the corrosion of a metal pipeline may be protected by the use of an electrical current.

Cathodic protection — Preventing corrosion of a pipeline by using special cathodes (and anodes) to circumvent corrosive damage by electric current

Cured-in-place pipe (CIPP) — A rehabilitation technique whereby a flexible resin-impregnated tube is installed into an existing pipe and then cured to a hard finish, usually assuming the shape of the existing pipe.

Closed-Circuit Television Inspection (CCTV) — An inspection method utilizing a closed-circuit television camera system with appropriate transport and lighting mechanisms to view the interior surface of epoxy-coated water mains.

Close-fit — A lining system in which the new pipe makes close contact with the defective pipe at normal or minimum diameter. An annulus may occur in sections where the diameter of the defective pipe is in excess of this.

Electrofusion — The joining together of parts using electrical energy.

Horizontal drilling — A steerable system for the installation of pipes, conduits and cables in a shallow arc using a surface launched drilling rig. Traditionally the term applies to large-scale crossings in which a fluid-filled pilot bore is drilled using a fluid-driven motor at the end of a bend-sub, and is then enlarged by a washover pipe and back reamer to the size required for the product pipe. The required deviation during pilot boring is provided by the positioning of a bent sub. Tracking of the drill string is achieved by the use of a downhole survey tool.

Microtunneling — A trenchless construction method for installing pipelines. Microtunneling uses all of the following features during construction: (1) Remote controlled – The microtunneling boring machine (MTBM) is operated from a control panel, normally located on the surface. The system simultaneously installs pipe as spoils are excavated and removed. Personnel entry is not required for routine operation. (2) Guided – The guidance system usually references a laser beam projected onto a target in the MTBM, capable of installing pipelines to the required tolerance, for line and grade. (3) Pipe jacked – The process of constructing a pipeline by consecutively pushing pipes and MTBM through the ground using a jacking system for thrust. (4) Continuously supported – Continuous pressure is provided to the face of the excavation to balance groundwater and earth pressures.

Pipe bursting — A replacement method. A technique for breaking the existing pipe by brittle fracture, using force from within, applied mechanically, the remains being forced into the surrounding ground. At the same time a new pipe, of the same or larger diameter, is drawn in behind the bursting tool. The pipe bursting device may be based on an Impact Molding tool to exert diverted forward thrust to the radial bursting effect required, or by a hydraulic device inserted into the pipe and expanded to exert direct radial force. Generally a PVC or HDPE pipe is used. Also known as Pipe Cracking and Pipe Splitting.

Polyethylene — A ductile, durable, virtually inert thermoplastic composed by polymers of ethylene. It is normally a translucent, tough solid. In pipe grade resins, ethylene-hexene copolymers are usually specified with carbon black pigment for weatherability.

PVC — Polyvinyl Chloride; a form of thermoplastic pipe.

Sliplining — (1) General term used to describe methods of lining with continuous pipes or lining with discrete pipes. (2) Insertion of a new pipe by pulling or pushing it into the existing pipe and grouting the annular space. The pipe used may be continuous or a string of discrete pipes. This latter is also referred to as Segmental Sliplining.

Spray lining — A technique for applying a lining of cement mortar or resin by rotating a spray head which is winched through the existing pipeline.

Trenchless technology — Techniques for utility line installation, replacement, rehabilitation, renovation, repair, inspection, location and leak detection, with minimum excavation from the ground surface.

Tunneling — A construction method of excavating an opening beneath the ground without continuous disturbance of the ground surface and of large enough diameter to allow individuals access and erection of a ground support system at the location of material excavation.

2. RATIONALE

The operations, maintenance, and management of a potable water system can be a complex process. With much of the potable water infrastructure buried (i.e., hidden), it is difficult to prioritize maintenance activities while continuously operating a reliable water system that meets the needs of the customers and the community. A water distribution system accounts for between 50 and 80 percent of the expenses incurred in the operation of an overall potable water system. Consequently, it should be operated, maintained, and managed as efficiently as possible, while providing high-quality potable water through a reliable water distribution system.

The scan done on prioritizing and choosing technologies for constructing and rehabilitating potable water linear systems was undertaken during the winter of 2001–2002 to see how and why municipalities across Canada were replacing/rehabilitating their water mains. The findings suggested that many municipalities would benefit from a best practice on how to select appropriate technologies for the rehabilitation or replacement of sections of a water distribution system that require remedial action. The knowledge gained from this best practice will allow municipalities to make better decisions with respect to capital investment priorities, operational and maintenance activities, water system security/reliability issues, and customer service levels.

It should be noted that this best practice assumes a municipality has already determined that remedial action on a section of its water distribution system is required. As such, the municipality now has to determine the best method to rehabilitate or replace the section of water main and the associated appurtenances that require remedial action.

3. UNDERSTANDING THE WATER DISTRIBUTION SYSTEM

The ultimate goal of any municipality is to provide water customers with a safe and reliable supply of high-quality drinking water, in sufficient quantities, while meeting customers' pressure requirements and service needs. This should be accomplished during maximum day demand periods (with an allowance for emergency fire fighting situations). Although the water distribution system is only one component of the overall potable water system, it can have significant impact on the customers it serves. Other critical infrastructure components include the water supply facilities (water plants or production wells), reservoirs, storage tanks, and pumping stations. Major elements concerning the distribution system that may impact on water customers include the operations of the water system, the associated maintenance activities (planned and emergency), and the level of customer service. Since this best practice focusses on the water distribution system, and the required rehabilitation or replacement of a section of water main, other issues that affect this best practice are only briefly discussed in the following sections.

3.1 OPERATIONS AND MAINTENANCE PRACTICES

It is well known that appropriate operations and maintenance activities can extend the life of the water distribution infrastructure and reduce or delay the need to rehabilitate or replace water mains or the associated components. Some major operational activities that have an impact on water mains include the quality of the water supplied into the distribution system, ongoing water quality monitoring throughout the system, water pressure management throughout the water system, field data handling (collection, storage, and management), and the operation and maintenance of system appurtenances, such as valves, fire hydrants and water service curb stops. One maintenance technique that has proven to extend the useful life of iron water mains in aggressive soils is the use of cathodic protection. Information on cathodic protection is available through AWWA, NRC/IRC or the National Association of Corrosion Engineers (NACE).

3.1.1 WATER CHARACTERISTICS

The chemistry of the water transported through the water distribution system can impact on the internal corrosion of unlined water mains. Understanding the chemistry of the water and its impact on the distribution system may allow a municipality to make changes to its water treatment processes to reduce or eliminate any internal corrosion problem. Any potential impacts of internal lining material exposure to soft or aggressive potable water should be addressed early in the selection process to ensure that long-term exposure will not adversely impact on the liner or on water quality. The use of daily water quality monitoring results (chlorine residual, turbidity, bacteriological quality, colour and pH) through a database can be a potentially good indicator of internal pipe condition.

The composition of the internal material of the water mains that is in continuous contact with the potable water can also have a direct impact on water quality. As such, a good water quality monitoring program within the distribution system can provide the information needed to ascertain if the internal materials of the water mains are affecting overall water quality. This, in turn, will provide valuable information to a municipality for prioritizing the rehabilitation or replacement of water mains based specifically on water quality parameters. Many other concerns must also be considered including hydraulic issues (pressure and flow), structural integrity of the water infrastructure, financial restrictions, conformity with existing specifications, and local community issues.

3.1.2 WATER PRESSURE

Water pressure management within a water system may have a major impact on the useful life of water mains. Water pressure surges (i.e., water hammer) should be avoided and controlled whenever possible. Proper operating procedures include appropriate pump start up and shut down, the speed of valve opening and closing, and the method of opening and closing fire hydrants during maintenance and other uses. The use of pressure-sustaining valves, pressure relief valves, air relief valves, and surge tanks within a water distribution system also helps maintain the integrity of a water distribution system. Water pressure also has a major impact on water loss within a water distribution system.

3.1.3 DATA HANDLING

The collection, storage, and management of operational and maintenance data can provide substantial insight into the issues affecting a water distribution system. Thus, determination of the type of operational data to collect, the best method of collecting and managing these data is important. Of particular importance is the fact that operational and maintenance activities (or the lack thereof) can significantly affect the deterioration rate of water infrastructure. If deterioration can be eliminated or minimized through better operational procedures or maintenance activities, this will reduce or delay the need to rehabilitate or replace sections of the water distribution system (i.e., extending the useful service life of the water mains). Data related to the operations and maintenance activities that have an indirect impact on the deterioration of water mains include:

- water system pressure readings throughout each and every day (the more pressure surges, the higher the probability of having water main structural problems, and higher water losses);
- maintenance activities related to water mains (number of water main breaks/repairs each year; water main flushing/swabbing/pigging programs;
- fire hydrant use or maintenance activities (fire flow testing; tanker truck filing);

- valve maintenance activities (location of boundary valves between two different pressure zones, pressure-reducing valves within the water distribution system, the method of opening and closing valves, valve operational status, valve location status);
- leak detection programs;
- reservoir use (impact on pressures and pressure surges); and
- infrastructure data on water mains (e.g., lengths, diameters, age, locations and depths), valves (e.g., types, sizes, age, locations, chamber and box details), fire hydrants (e.g., types, flows), water services (e.g. size, type, number, location, depth and material).

3.2 REGULATORY REQUIREMENTS

A municipality must be aware of all federal, provincial, territorial, municipal and other regulatory requirements that may impact the process and cost of selecting a rehabilitation or replacement technology. Regulatory impacts could, if significant enough, change the financial outcome.

3.3 SUBSURFACE INVESTIGATION

For any type of buried infrastructure work, an understanding of the type and condition of the soil, and any possible infrastructure conflicts is critical. Depending on soil conditions and water table levels, the options for rehabilitating, replacing, or repairing a water main section may be limited. As such, a geotechnical investigation is normally undertaken to confirm soil conditions and any possible infrastructure conflicts before designing any options to rehabilitate or replace a section of water main. It is advisable to have geotechnical investigations undertaken by staff or organizations specialized in this field of work.

3.4 FINANCIAL ISSUES

Finances always play a role in water main rehabilitation or replacement. A structured approach is suggested, including a prioritization process to determine which section of water main should be rehabilitated or replaced first. An infrastructure rehabilitation/replacement plan should be prioritized based on overall best value to the community. In many cases, a prioritization and scheduling model may be required to allow for different financial options that consider budget availability, resource constraints and other community factors.

3.5 COMMUNITY ISSUES

Many community issues come into play when determining which section of water main to rehabilitate or replace. These include growth issues, environmental concerns, urban and rural development issues, health and safety, the impact on businesses, risk assessment, other infrastructure co-ordination issues (sewer and roads primarily), and the criticality of water service (e.g., water supply to a hospital).

4. SELECTION OF APPROPRIATE TECHNOLOGIES

4.1 CONSIDERATIONS

This best practice provides guidance in selecting technologies for rehabilitating or replacing sections of water distribution systems. While this document touches on the main issues associated with selecting an appropriate technology, it is impossible to cover every possible situation. It is recommended that a municipality without the in-house expertise, hire or engage a specialist in this field to guide it through the steps in rehabilitating or replacing the section of water infrastructure requiring remedial action. This specialist can provide the following expertise:

- up-to-date information on developments in the various technologies on the market;
- insight into local community issues that should be considered throughout the selection process; and
- good quality assurance and quality control mechanisms to make certain the requirements of the contract have been met.

Many municipalities do not feel comfortable trying new technologies that have not been proven in their community. Each municipality has infrastructure and conditions that are unique in many ways, and concerns about the applicability of a new technology may deter them from replacing or rehabilitating a section of water main by a technology other than the open cut method. If thorough research on the various alternative technologies does not satisfy a municipality, we recommend a pilot installation, which may address any construction issues, health and safety, environmental and other possible concerns. Site visits to other communities who have tried new technologies is also recommended.

Other critical items to consider before selecting an appropriate rehabilitation or replacement technology include the size of the contract, local availability of the technology, possible impacts of water main material to be used (i.e. potential expansion/contraction issues) and the density of water services on the water main being considered for remedial action.

4.1.1 SIZE OF CONTRACT

The size of the contract can preclude some technologies as it may not be economical to have specialized equipment and personnel travel long distances for smaller contracts. Initial mobilization and demobilization for some specialty technologies can be expensive. With larger contracts, more options will be available for various technologies. Coordination of similar types of construction

activities with surrounding municipalities may make some of the technologies more economical.

4.1.2 LOCAL AVAILABILITY

Local availability is also critical as some regions across Canada may have very little local presence of some of the newer technologies. Availability should be considered in the selection evaluation, allowing the municipality to narrow the options more quickly. This factor is directly linked to the size of the contract, as a larger contract may attract companies from other regions of Canada or the United States. As well, an alternative may be to have an outside specialist work with a local contractor on one or two initial projects, thereby transferring the technology and promoting future local availability.

4.1.3 WATER MAIN MATERIAL

The selection of the water main material may have an impact on the rehabilitation or replacement technology. There are various water main materials on the market for new pipe and rehabilitation technologies. Expansion and contraction (i.e. creep) is a factor that must be considered when selecting and designing the water main.

4.1.4 DENSITY OF WATER SERVICES

The quantity and, more importantly, density of water services connected to the water main requiring remedial action may play a large role in selecting alternative technologies. This statement assumes that even when a trenchless technology is used to rehabilitate or replace a water main, the water service will be replaced by the excavation method (i.e., not by a trenchless technology). As a general rule, if there are more than 20 water services per 100 metres of length of the water main requiring remedial action (i.e., two water services at 10-metre intervals or less), then open cut replacement is likely the most economical solution.

This guideline is only based on the actual construction work and does not include other community concerns. Using a different rehabilitation or replacement technology at a higher construction cost to the open cut method may be in the best interests of the community. When other issues are considered, such as traffic, impacts on commercial and industrial customers, water quality, and environmental and safety concerns, cost may play less of a factor in the final decision-making process. This is why it is essential for municipalities to have a well thought out rehabilitation or replacement selection process.

It should also be noted that if the technology does not require any external intervention, the density of water services becomes less of a significant factor.

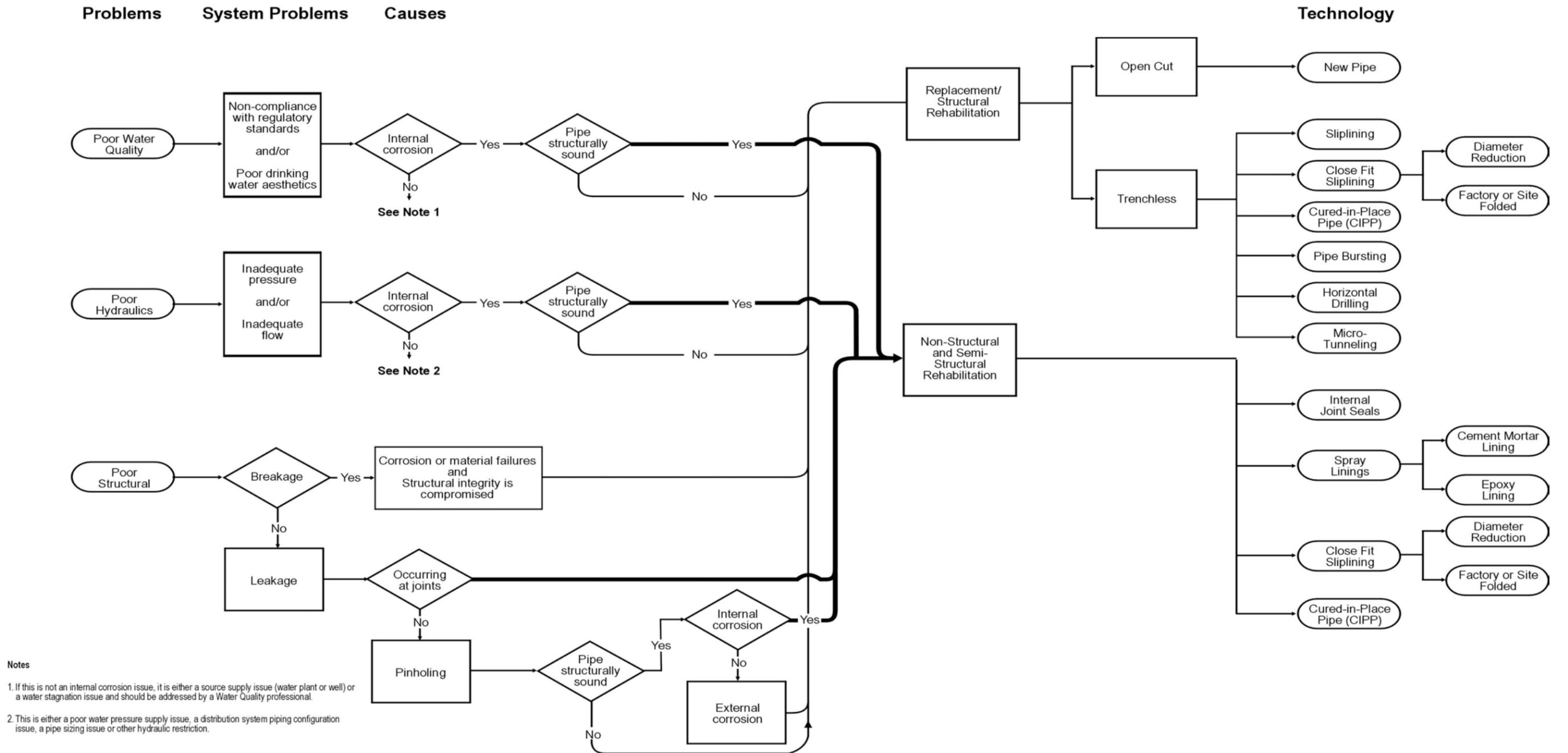
4.2 SELECTION OF THE REHABILITATION OR REPLACEMENT TECHNOLOGY

The flow chart in Figure 4–1 identifies the process for a municipality to follow in determining the technologies available for a specific situation. The flow chart first identifies the problem(s) that initiated the requirement to rehabilitate or replace a section of the water distribution system. It then addresses the possible system problems and their causes, two available options, and the various rehabilitation or replacement technologies.

The initiating problems, system problems and causes have been discussed previously, or are self-explanatory. The available options focus on two possible alternatives: replacement/structural rehabilitation, or non-structural and semi-structural rehabilitation. The AWWA Manual of Water Supply Practices (M28) *Rehabilitation of Water Mains*, second edition (2001) refers, on page 4, to those classifications for lining techniques as follows: CLASS I (non-structural), CLASS II/III (semi-structural) and CLASS IV (structural). Replacement would be considered structural. Again, it should be noted that although cathodic protection is a technique available to mitigate corrosion and extend the useful service life in corrosive soils, it is not considered a rehabilitation technique but a maintenance technique. As such, it is not included in this flow chart.

Each technology can meet specific needs based on the structural integrity of the section of water main requiring remedial action. These technologies are well addressed in various reports and manuals. The AWWA Manual of Water Supply Practices (M 28) *Rehabilitation of Water Mains*, second edition (2001), and the Water Environment Research Foundation report *New Pipes for Old: A Study of Recent Advances in Sewer Pipe Materials and Technology* (2000), were the two primary resources used to describe these technologies. Since technology is changing at a rapid pace, it is recommended that references be viewed with this in mind. The experiences and knowledge of the Best Practice Working Group members also provided supporting information.

Selecting Appropriate Technologies for Rehabilitating or Replacing a Water Main FLOW DIAGRAM



Notes
 1. If this is not an internal corrosion issue, it is either a source supply issue (water plant or well) or a water stagnation issue and should be addressed by a Water Quality professional.
 2. This is either a poor water pressure supply issue, a distribution system piping configuration issue, a pipe sizing issue or other hydraulic restriction.

Figure 4-1: Flow Chart for Selecting the Rehabilitation or Replacement Technology

4.2.1 NEW PIPE

The installation of new water mains by continuous trenching is frequently referred to as the open cut method. This method is well documented, and most municipalities have good design and construction specifications for these types of projects. The installation of new replacement pipe should only be undertaken when the review of all alternate technologies has been completed and the open cut method is ranked as the best alternative.

Benefits

- A new water main is installed, complete with all new appurtenances.
- The water main system is upgraded to current specifications and standards.
- The water main can be aligned to meet the needs of the local area.
- Water service lines can be upgraded in material and diameter, and lowered to meet current standards.
- Water main sizing can be changed to meet current and future maximum day and fire flow requirements.
- Other infrastructure can be rehabilitated or replaced at the same time, allowing for coordinated work and sharing of costs.

Drawbacks

- The cost of the open cut method can be substantial compared to some of the newer technologies.
- The construction duration may be substantially longer than most trenchless technologies due to the amount of disturbance to other infrastructure and traffic, as well as the amount of reinstatement work required following the installation of the water main.
- There are more safety concerns due to traffic issues on road right-of-ways, the number of excavations required, and the large, heavy equipment needed to perform the work.
- There can be significant disturbance to other surface and buried infrastructure which may result in costly relocations.
- Social and environmental costs of major open cut projects may be substantial during construction.

4.2.2 SLIPLINING

Sliplining is the insertion of liners of various materials directly into the water mains. Either continuous or jointed discrete lengths of pipe are pulled/pushed

through the existing water main. Sliplining creates a new, integral pressure pipe inside the old water main without needing a complete excavation. The sliplined pipe is then reconnected to the existing water main at both ends.

High-density polyethylene (HDPE) pipe is the primary material used for sliplining. Other materials are also available and are listed in Table 4–1. HDPE pipe is butt fused (thermal process) in various possible lengths above ground, then inserted into the host water main at entry pits. While the benefits of grouting the annular space has traditionally been an industry debate, the NRC-IRC recently produced a Construction Technology Update (No. 57) on this issue. It would be beneficial to review this Technology Update, which is published on IRC’s Web site.

Jointed discrete lengths of pipe can also be used for sliplining, although this method is principally used in storm and sanitary sewer applications. These pipe lengths are joined by collarless methods, such as screw threads on the end of the pipes or snap-lock joints. This method allows shorter lengths of pipe to be inserted from an entry pit. It also requires less working space at the surface of the job site.

A sliplined pipe substantially reduces the cross-sectional area of the pipe. However, the reduction in the friction factor of the lined pipe compared to the previous, old unlined pipe could significantly compensate for the reduced internal diameter. Hydraulic requirements must be considered carefully before selecting sliplining as a preferred alternative.

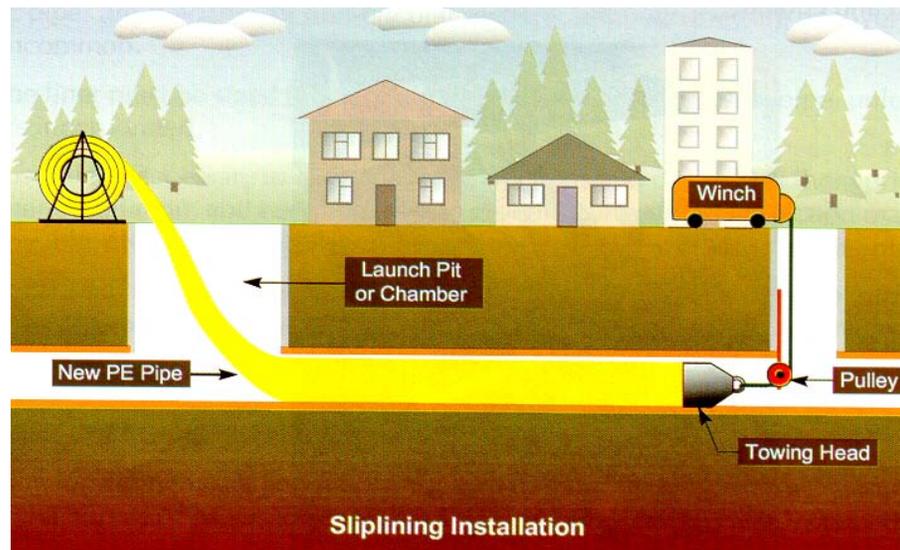


Figure 4–2: Sliplining installation
(Courtesy of Hastak, Makarand and Gokhale, Sanjiv)

Benefits

- Sliplining can be applied to most types of pipe.
- It has an independent structural integrity and is not reliant on the integrity of the host pipe.
- It is rapid and causes little disturbance to other utilities (when grouted, it is generally slower than other rehabilitation technologies).
- It is an efficient technique to consider when there are long runs with few connections.
- Usually, this method provides a better friction coefficient for improved hydraulic performance compared to the host pipe prior to rehabilitation.

Drawbacks

- The sliplined pipe should be sized so its outside diameter is at least 10 percent smaller than the inside diameter to allow for smooth insertion. This reduction, in association with the wall thickness of the pipe, will cause a loss of cross-sectional capacity and can impact on hydraulic capacity.
- When short pipe sections are used, there is an increased cost for joining pipes.
- Poorly controlled grouting to the annular space can lead to the liner pipe buckling.
- Multiple excavations may be required if many service and branch reconnections are involved.
- The liners used for sliplining generally do not turn well through bend fittings. In most practical applications, all bend fittings must be excavated. As such, the geometry of the unlined pipe must be considered before selecting this technique.

4.2.3 CLOSE FIT SLIPLINING: DIAMETER REDUCTION

Close fit sliplining involves inserting a thermoplastic tube that has been temporarily deformed to allow sufficient clearance for insertion into the host pipe. The tube is subsequently returned to its original shape and diameter, providing a close fit in the host pipe. The outside diameter of the tube is the same or slightly larger than the inside diameter of the host pipe. The tube is passed through either a set of static dies (referred to as swaging), or through an array of compression rollers, which reduce the tube diameter to allow for insertion by winching after winch insertion is complete. The tube then reverts to its original dimensions once the winch tension is released. The process of reversion may be aided or accelerated with the help of internal water pressure.

Benefits

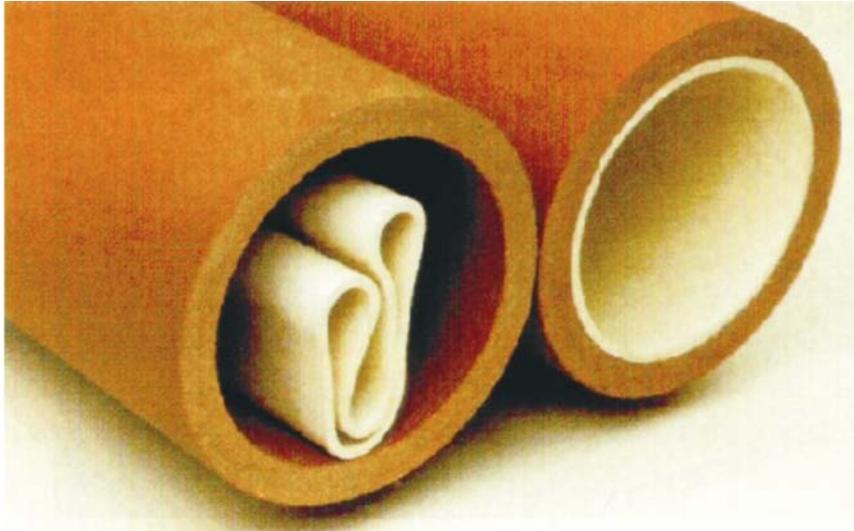
- Close fit diameter reduction sliplining can be applied to most types of pipe.
- It is rapid and causes little disturbance to other utilities.
- It is a useful technique when there are long runs with few connections.
- It usually provides a better friction coefficient for improved hydraulic performance.
- There is minimal loss of pipe diameter and no grouting compared to the traditional sliplining technique.
- The liner can provide either full structural integrity or semi-structural integrity, depending on the condition and sizing of the host pipe.

Drawbacks

- The energy required to reduce the pipe diameter increases dramatically with larger pipe sizes and greater wall thicknesses.
- The tube being installed may get hung up in pipes that are deformed, have dimensional irregularities, or displaced joints.
- Manufactured pipe for insertion usually requires special extrusion dies due to non-standard pipe diameters.
- Sufficient site space is required to accommodate butt-fusion welding of pipes before the diameter reduction and during insertion.
- As with standard sliplining, the geometry of the host pipe must be considered, as the winched pipe generally does not turn well through bent fittings.

4.2.4 CLOSE FIT SLIPLINING: FACTORY OR SITE FOLDED

Depending on the material used, this technique is based on either the liner being heated and folded at the manufacturer's factory, then transported to the installation site on a reel or site folded (typically HDPE) and not coiled. The folded liner is winched into the host pipe and re-rounded using a combination of heat (typically steam) and pressure and, at times, a device propelled through the liner.



Folded PVC liner
for watermain
renovation, showing
close fit after
reversion

Figure 4–3: Close fit sliplining
(Courtesy of Hastak, Makarand and Gokhale, Sanjiv)

Benefits

- Close fit, site-folded sliplining can be applied to most types of pipe.
- It is rapid and causes little disturbance to other utilities.
- It is an efficient technique to consider when there are long runs with few connections.
- It usually provides a better friction coefficient for improved hydraulic performance compared to the host pipe prior to the rehabilitation process.
- There is minimal loss of pipe diameter and no grouting compared to the traditional sliplining technique.
- The liner can be selected to provide either full structural integrity or semi-structural integrity, depending on the condition and sizing of the host pipe.
- The liner can be used in host pipes with bends up to 45°, with some internal ovaling and/or ridging.
- The site-folded technique is less sensitive to the variations in diameter or pipe with dimensional irregularities, compared to the diameter reduction technique.

Drawbacks

- There is still uncertainty in the industry regarding the folding and re-rounding process of the liner, and its affect on the long-term pressure capability of the liner.

- The reversion process may sometimes not be completed fully.
- The liner may move in relation to the host pipe due to the type of material used and inherent stresses that may be locked into the liner. (Proper design may alleviate this concern.)

4.2.5 CURED-IN-PLACE PIPE

With cured-in-place pipe (CIPP), a fabric tube is impregnated with a thermosetting resin before insertion into the host pipe. The resin is then cured in the host pipe to produce a rigid pipe within the host pipe. The combination of the fabric material, with or without fibres, and the resin can be designed to produce a new pipe that has full structural capabilities, semi-structural capabilities or non-structural capabilities. The resins used for potable water applications must meet National Sanitation Foundation (NSF) and local health authority approvals.

The fabric material can be tailored in the factory to suit the diameter of the host pipe. CIPP liners can negotiate 90° bends within the host pipe.

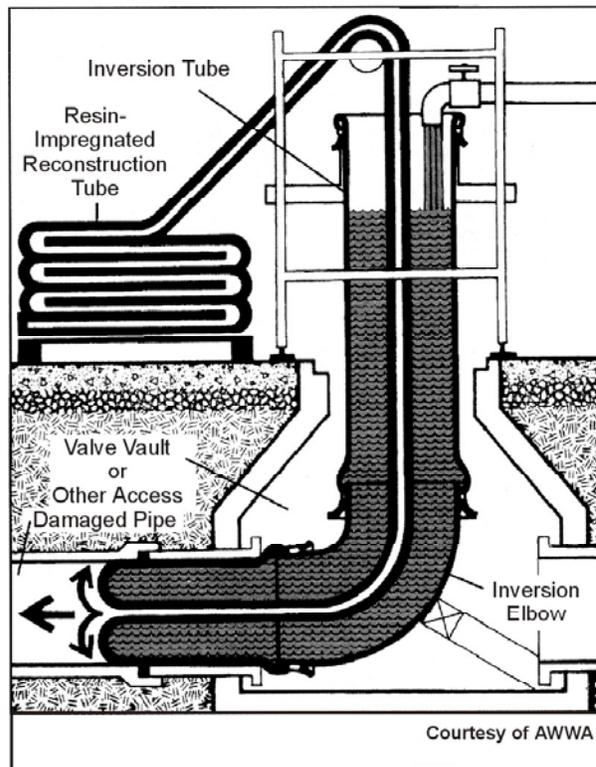
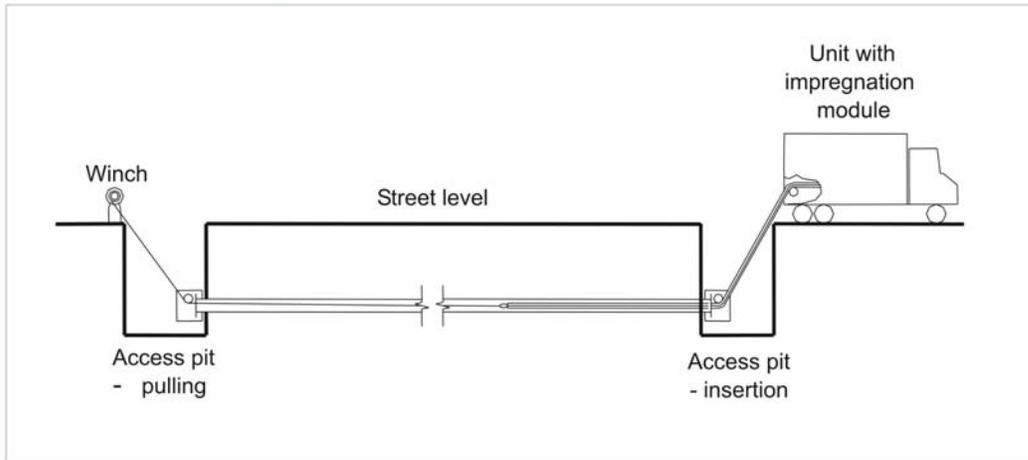


Figure 4–4: Filling the tube-feeding standpipe with cold water (inversion method)

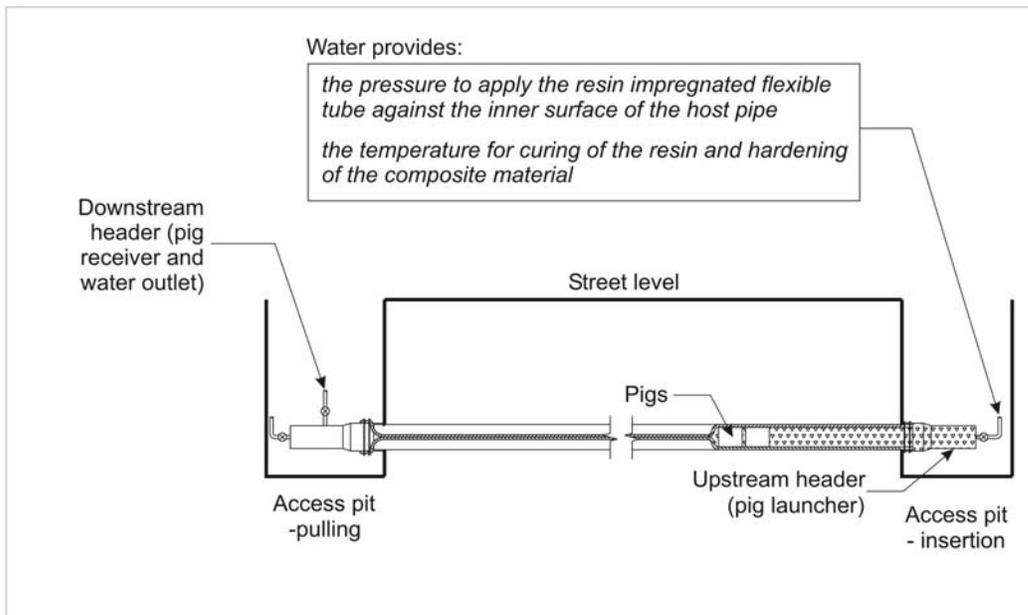
There are three main classification groups of CIPP systems. These are available independently or as a combination of the three: woven hose, felt-based and membrane systems. CIPP liners can be pulled into the host pipe and expanded with water pressure prior to curing (Figure 4–5) or installed by inversion in

which the liner is turned inside out in the host pipe by water pressure (Figure 4-4).

Insertion of a CIPP liner in a watermain



Forming and curing of CIPP liner



Source : Sanexen Environmental Services inc.

Figure 4-5: Felt Based Liner (pulled-in method)

There are three main CIPP systems.

Woven Hose System

This system is used in water mains where the structural integrity of the host pipe is compromised, because of a history of breaks, external corrosion, leakage due to faulty joints, pinholes or internal corrosion. These liners can either provide full structural integrity or semi-structural integrity depending on the condition of the host pipe. The liner is normally impregnated on site, inserted and made to adhere to the host pipe. Services are generally opened from the inside after curing. The quality of the cleaning of the host pipe before insertion of the liner is important.

Felt-Based Liner System

The felt-based liner is made of non-woven polyester felt, coated on one face with a layer of elastomer. The felt-based liner can include reinforced fibres to provide full or semi-structural integrity of the liner. The resin used in this application also plays a large role in the structural integrity of the new liner. The liner is normally impregnated with the resin at the factory then transported to the site for installation. The transportation to the site frequently occurs in a refrigerated truck to prevent premature setting of the resin. For larger-diameter liners, the resin is sometimes applied on site.

Membrane System

This liner system is inserted into the host pipe with an elastomeric membrane impregnated with resin. This membrane is very thin and was initially designed for low-pressure gas main rehabilitation applications (less than 70 kPa or 10 psi). A membrane system is suitable for non-structural water main rehabilitation applications and offers internal corrosion protection. It can bridge very small pinholes and joint gaps.

It should be noted that in some instances the service connections can be reinstated from inside the pipe with the use of robotics, depending on the type of liner used.

Benefits

- Installation is relatively fast with minimal excavation.
- Access to the water main is gained from an existing access hole.
- The system can accommodate a variety of diameters and can negotiate bends.
- Service connections can be reinstated by robotic cutters, reducing excavation requirements.
- An improved interior friction coefficient increases hydraulic capabilities, even with the slight loss in cross-sectional area.

- It can be used in structural, semi-structural, and non-structural applications.

Drawbacks

- As the diameter increases, the difficulty of installation increases.
- The host pipe needs extensive up front investigation and planning to determine locations of appurtenances prior to cleaning and preparation.
- The liner is flexible and requires support from the surrounding material before curing.
- Under and over cuts at service connections may occur occasionally.
- The weight of the liner may cause partial buckling and ovality during installation (usually associated with the inversion process).

4.2.6 PIPE BURSTING

Pipe bursting is a trenchless technology that replaces a water main by breaking and displacing the existing pipe and installing a replacement pipe in the void created. The system uses a pneumatic, hydraulic or static bursting unit to split and break up the pipe and compress the materials into the surrounding soil. The new replacement pipe is simultaneously pulled or pushed with the bursting head to fill the void created (see Figure 4–6).

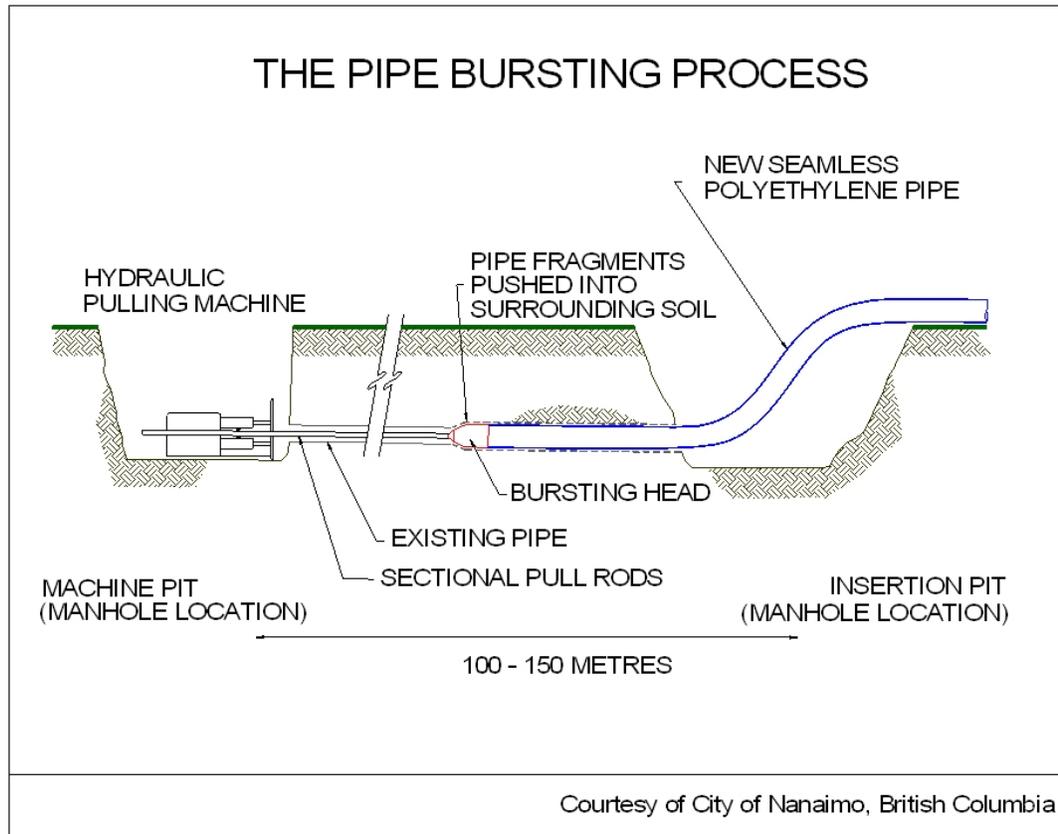


Figure 4–6: Pipe-bursting process

It is possible to upsize to about 30 percent greater than the diameter of the existing pipe, but this depends on soil conditions, the proximity of other existing structures, and the depth of cover. The pulling force of the bursting unit must be maintained at a value less than the tensile strength of the replacement pipe to avoid overstressing the new pipe. The replacement pipe must be installed in one continuous length. Because of this, butt-fused PE pipe is used in most cases.

Water service connections, valves, fire hydrants, and other appurtenances connected to the water main to be rehabilitated should be excavated and exposed before starting the pipe-bursting process. As well, all pipes and underground structures within one metre of the water main to be rehabilitated by bursting should be excavated and exposed to avoid damage due to the forces transmitted through the soil during the pipe-bursting process. The presence and location of repair clamps on the existing pipe are also important to know so the bursting equipment can deal with the clamps.

Benefits

- Cleaning the existing pipe is not necessary.
- A larger diameter pipe can be inserted. This, in conjunction with the improved interior friction coefficient, can substantially increase the hydraulic capabilities of the new water main.
- The process provides for full structural rehabilitation.
- It is most successful when there are long runs with few connections.

Drawbacks

- Pit excavations are normally required to accommodate replacement pipe sections.
- All water main appurtenances must be excavated before bursting and then reconnected to the new water main.
- All underground structures within one metre of the existing water main to be rehabilitated may have to be excavated to avoid damage that may occur due to the force being transmitted, and the displacement of soil, by the bursting technique.
- Surface or roadway may be susceptible to heaving or slumping.
- Potential scoring damage to outside of new pipe wall may impact new water main material.
- There is limited quality control of pipe bedding and sidefill support.

4.2.7 HORIZONTAL DRILLING

Horizontal drilling, frequently referred to as 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. Depending on the size of bore required, successive reamers are then pulled back to enlarge the bore diameter to the desired size. During the last stage of the reaming, the service pipe is pulled back into the bore.

This method is frequently employed when an open-cut excavation is completely unsuitable (such as at a railway crossing), and a new water main alignment is desired. 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.

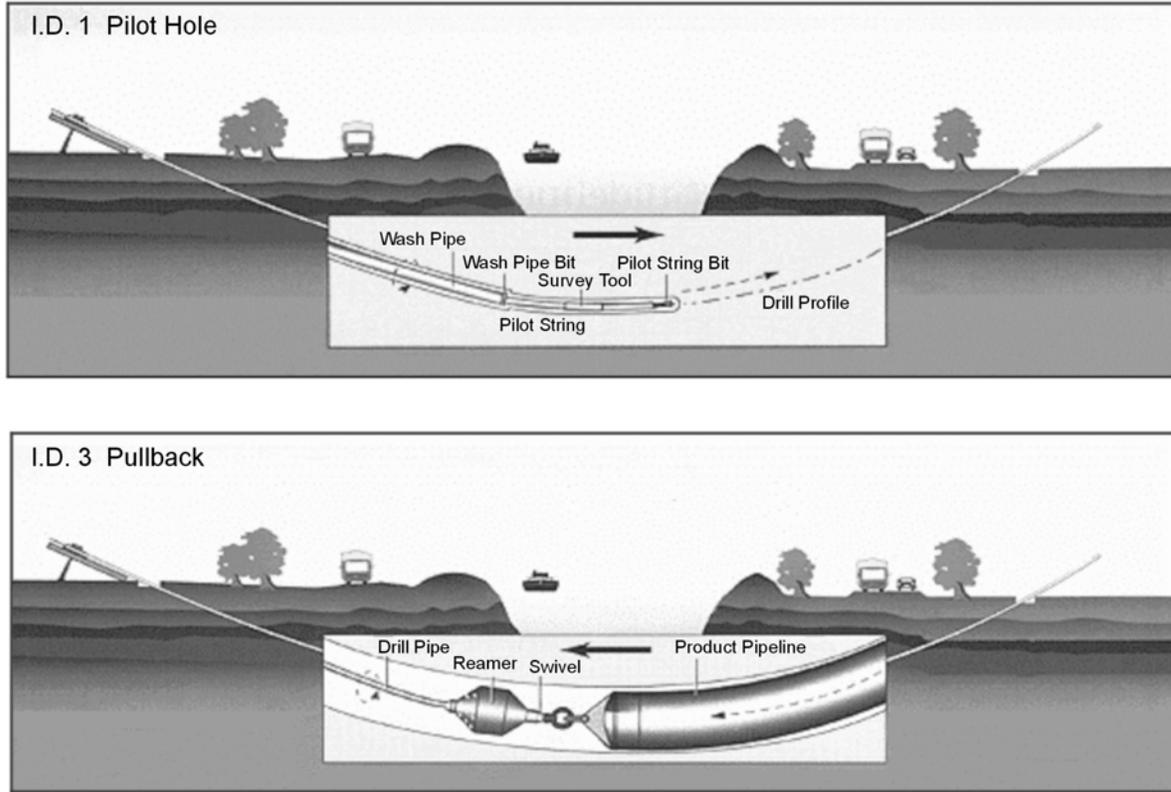


Figure 4–7: Horizontal drilling
(Courtesy of Hastak, Makarand and Gokhale, Sanjiv)

Benefits

- There is reduced disruption to surface operations, such as major thoroughfares, railway tracks, rivers, buildings, and trees.
- Disruption of buried infrastructure is reduced compared to the open-cut method.
- The method allows for a new water main alignment.
- Usually, there are lower restoration costs than with the open-cut method.

Drawbacks

- Larger working areas are normally required compared to other trenchless technologies, to accommodate drilling equipment and pipe material.
- Exact pipe alignment can be difficult to attain, although the method is still fairly accurate.
- The length of the pipe being installed is limited by the diameter of the pipe (the larger the diameter, the shorter the possible span).
- Consistent soil conditions are normally required for good performance.

- There is limited quality control of pipe bedding and sidefill support.

4.2.8 MICRO-TUNNELLING

While micro-tunnelling is normally used for very deep, usually new installations, applications have included rerouting existing water mains.

Micro-tunnelling is different than full tunnelling in that the process uses a remotely controlled boring machine combined with the pipe jacking technique to install pipelines. Experts in this field should be engaged for any application of this technology. Like horizontal drilling and pipe bursting techniques, there is limited quality control of pipe bedding and sidefill support.

4.2.9 INTERNAL JOINT SEALS

An internal joint seal makes the inside surfaces of leaking pipe joints watertight. The seal's flexibility ensures a bottle-tight seal around the entire pipe joint, while its low profile and graded edge allows water to flow without creating turbulence. Internal joint seals are made of ethylene propylene diene monomer (EPDM) synthetic rubber. This technique requires worker access to the water main by the work crew to perform the installation. Because of this, pipe diameters of 600 mm or greater are good candidates for this technology.

Internal preparation of the pipe is important for internal joint seals to perform to specifications. The pipe joints must be completely cleared of debris and dust, and the area on either side of the joint prepared to accommodate the lip of the seal.

Once the cleaning is completed, Portland cement is generally used to fill the joint gap completely and make it flush with the internal surface of the water main. Before applying the seal, the area must be cleaned with a dry brush and coated with a lubricant soap compatible with the type of seal being used. The lubricant soap is only an aid for installing the seal. The seal is then positioned to span the gap. Stainless steel retaining bands are installed in the grooves of each seal. A hydraulic expanding device is used to apply the correct pressure to the retaining bands, thereby keeping the seal in place. Pressure testing is generally conducted prior to acceptance.

Benefits

- This technology is specific to pipe joint issues only.
- Minimal working space is required at the surface.
- It is a low-cost alternative.

Drawbacks

- It can only be used in pipe sizes suitable for worker access (i.e., 600 mm diameter or larger).
- The technique does not address other possible pipe line deficiencies.

4.2.10 SPRAY LININGS: CEMENT MORTAR

With a cement mortar lining, cement mortar is applied to the pipe wall by the rotating head of a machine. When cement mortar is applied to the wall of an iron pipe, oxidation of the pipe wall ceases, because cement mortar is porous, allowing the water in the water main to penetrate through it and make contact with the iron material of the pipe wall. Deterioration of the pipe wall does not occur because, as the water passes through the cement mortar, it becomes alkaline and a chemical inhibitor against oxidation forms.

Lining a water main with cement mortar not only reduces internal deterioration of the main, it also eliminates or reduces the need to flush the water main due to red water concerns in the water main being lined. The lining of water mains with cement mortar is usually undertaken in water mains that are considered structurally sound. Cement mortar applications with a semi-structural capability can also be accomplished by applying an initial, coat of cement mortar, then installing a wire mesh that runs the complete length of the main being rehabilitated. A second coat of cement mortar is then added. The semi-structural cement mortar application requires access by workers to install the wire mesh and, therefore, is only suitable for water mains of 600 mm diameter or greater. Water service lines must also be exposed before the installation of the wire mesh.

The application of the cement mortar requires a completely cleaned and dewatered pipe. The pipe must be free of standing water, which typically appears at low points. All line valves must be removed and replaced, or their bonnets must be removed to clean the cement mortar from the interior of the valve if the water main is too small for a person to enter and manually clean the cement mortar from the valves. Most cement mortar lining equipment can accommodate small bends (less than 22.5°) and, depending on the diameter of the water main being lined, larger bends (up to 45°) can be accommodated. The mortar is usually pumped through hoses to the lining machine as it is being applied.

Once the cement mortar is applied, the water service lines of 50 mm in diameter or less must be cleared by blowing compressed air or letting water run back through the service line. Properly clearing the service lines is critical to make certain service lines do not get plugged or restricted. Service lines greater than 50 mm in diameter generally do not get plugged by the cement mortar lining application if proper construction techniques are used. To cure the mortar, either the ends of the pipe section are capped and left to cure for 12 to 24 hours or 24 hours after completion of the lining, water is introduced into the line without pressure. Water mains with low flows may experience high pH problems for a

short time due to the high alkalinity of the newly applied cement and the aggressiveness of the water within the pipe.

The AWWA has developed a standard for cement mortar lining applications for water main diameters of 100 mm and larger. It is recommended that the AWWA C602 standard be adhered to during any water main cement mortar application.

Benefits

- Minimal excavation is required.
- Compared to most other rehabilitation technologies, pipe diameter reduction is not significant (with the exception of epoxy lining).
- The method can accommodate a variety of diameters and negotiate bends.
- Service connections do not have to be excavated to return to service.
- The improved friction coefficient increases hydraulic capabilities.
- The method can be used in semi-structural and non-structural applications.
- It reduces yearly maintenance activities (flushing) and customer complaints due to reduced red water.

Drawbacks

- A completely clean and water free main is required, which means all valves and service connections must be watertight.
- Butterfly valves or valves that are not full diameter must be removed.
- Access to customer homes and businesses is usually required to isolate every water service line, and to apply either water or compressed air to clear the service connections after the lining process.
- This technique can temporarily affect the pH values of the water.

4.2.11 SPRAY LININGS: EPOXY

Lining a water main with epoxy is typically a non-structural rehabilitation method. New semi-structural methods are under development. The initial process of preparing the water main is similar to the cement mortar lining technique, in that a completely clean pipe is required, free of any debris or water. Epoxy is a dielectric insulator that stops flow of negative ions off the iron surface and into the electrolyte (water). Therefore, if the epoxy does not provide electrical insulation due to voids in the coating, corrosion can occur. Epoxy lining provides this dielectric barrier to corrosion which is different than the passivation process of cement mortar lining. The host pipe must not have any pinholes or other

possible leaks in the pipe wall. As such, connecting water mains or appurtenances must be completely water tight to not allow any water to enter the water main being lined. The epoxy lining process involves the application of a very thin layer (1 mm) of resin and hardener to the pipe wall. The appropriate mixture and temperature of the resin and hardener is critical for durability and cohesiveness. Because of this, computerized machinery with heating devices is used in the application. The application equipment is winched through the water main at a uniform rate to ensure the proper mixture and thickness are applied.

After lining, the ends of the water main are capped and the resin is allowed to cure at an ambient temperature (must be above 3° C). Water service connections to the newly relined water main do not have to be either backflushed with water or blown with air, as is the case for the cement mortar lining application method. On completing the curing process (normally 16 hours), the pipe should be inspected visually or by closed-circuit television. The water main is then flushed and disinfected before being put back into service.

Review of the Water Research center (WRc) *Manual and Code of Practice* (third edition) (2002) is recommended before attempting this technology.

Benefits

- Minimal excavation is required.
- There is very little loss of pipe diameter (2 mm) as a total thickness of 1 mm of epoxy is applied.
- The method can accommodate a variety of diameters and negotiate bends.
- Service connections do not have to be excavated to return to service.
- The improved friction coefficient increases hydraulic capabilities.
- The method reduces yearly maintenance activities (flushing) and customer complaints due to reduced red water.

Drawbacks

- A completely clean and dry water main is required, which means all valves and service connections must be watertight.
- Butterfly valves or valves that are not full diameter must be removed if not being replaced as part of the rehabilitation process.
- Access to customer homes and businesses may be required to isolate every water service line before the lining process begins.

Table 4-1: Limitations of Technologies

Technology ⁽¹⁾	Diameter Range (mm)	Maximum Installation Range (m)	Rehabilitation Capability			Liner Material ⁽²⁾
			Full Structural	Semi-Structural	Non-Structural	
Sliplining						
- Continuous	100 to 1600	300	X			PE, PVC, PP, PE/EPDM
- Discrete sections	300 to 4000	1700	X			PE, PVC, PP, GRP, DI
Close-fit sliplining						
- Diameter reduction	100 to 1000	100	X	X		PE, PP
- Site folded	100 to 600	600	X	X		PE, PVC, FRP
Cure-in-place						
- Felt based	100 to 2750	1000	X	X		Non-woven polyester fibre Woven polyester fibre Elastomeric membrane (note that all of the above include resin impregnation)
- Woven Hose	100 to 1016	1000	X	X	X	
- Membrane	100 to 2750	1000			X	
Pipe bursting	50 to 1200	150	X			PE
Horizontal drilling	100 to 1200	600	X			PE, PVC, DI, steel
Micro-tunnelling	300 or larger	200	X			Concrete, DI, PE, PVC
Internal joint seals	400 or greater	No limit	X			EPDM(structural at a joining seal location only)
Cement mortar lining	100 to 4500	500			X	Cement mortar
Epoxy lining	100 to 4500	500			X	Epoxy, Polyurea

Notes:

- (1) New pipe is not listed in this table but can be considered to have no limitations with respect to the headings identified in this table.
- (2) PE = Polyethylene; PVC = Polyvinyl chloride; PP = Polypropylene;
PE/EPDM = Polyethylene/Ethylene propylene diene monomer; DI = Ductile iron.

5. APPLICATIONS AND LIMITATIONS

5.1 FREQUENCY

This best practice should be undertaken on an as-required basis whenever a water main has to be replaced or rehabilitated.

5.2 RISKS

Not undertaking this best practice means a municipality has decided to maintain its current method of evaluating how to replace or rehabilitate water mains. If a municipality is staying aware of water main rehabilitation and replacement technologies through organizations, such as the AWWA, NASTT, and others, and is applying these best practices, there is probably little risk. But, if a municipality is not aware of these organizations or their best practices, then there is a risk associated with not operating, maintaining, replacing, or rehabilitating the water infrastructure in the most efficient, effective, and environmentally sound manner. This, in turn, probably means the municipality is not taking best advantage of the newest technologies, and is most likely spending more on the replacement or rehabilitation of its water infrastructure.

5.3 EXPECTED OUTCOMES

If a municipality applies the suggested approach of this best practice, it should expect to have the knowledge required to make sound decisions regarding the replacement or rehabilitation of its water infrastructure. This, in turn, provides benefits to the municipality by maximizing use of limited investment dollars while respecting customer needs and the environment.

APPENDIX A: CASE STUDIES

The three sample case studies follow the steps in the flow chart (Figure 4–1) for selecting appropriate technologies for the rehabilitation or replacement of sections of water mains that require remedial action. The intent is to show municipalities first hand how the selection of a technology took place in another community.

Case Study No. 1

Basic Problem:

To restore the structural integrity of a 70-year-old (300 mm) cast iron water main, which ran under a rail line, without disturbing the rail line, and with minimal flow and pressure reductions for customers.

Causes:

The water line failed due to age, location under a rail line, and corrosion.

Outcomes:

Three options (repair, abandon, or renew) were considered. The preferred option was sliplining. (Abandoning was not a possibility.) It was carried out at reasonable cost, with minimal disruption to customers, with positive media and local business community feedback. Indeed, the project was considered innovative by the rail line (CNR). In addition the technology transferred from a specialist to local contractors and city crews, and will be considered in the future.

Case Study No. 2

Basic Problem:

To restore the structural integrity of 140 km of 1950/60s vintage residential 150 mm and 200 mm unlined cast iron water mains which were causing rusty water complaints and high breakage rates. A single rehabilitation/replacement approach was not economically feasible and non-structural epoxy lining was also not feasible due to the significant break rates. Hydraulic capacities were sufficient.

Problems caused by the reduced structural integrity of the mains included disruptions of service, poor water aesthetics, many road cuts, increasing maintenance costs, the costs associated with water loss, damage to pipe bedding, water infiltration into sewers, and undermining of sewers.

Causes:

The unlined cast iron was failing due to both internal and external corrosion. Frost heaving, poor installation techniques, aggressive soils, and recent road work increased pipe loadings.

Outcomes:

The municipality considered either open-cut or cured-in-place options depending on the circumstances.

The open-cut method was used in older areas where sewers also required rehabilitation and an increased burying depth to meet current standards. Joint rehabilitation of sewer and water mains was selected.

The cured-in-place method was used in other areas where total sewer replacement was not required, and spot repairs of sewers could be undertaken using trenchless techniques. Due to the high density of residential servicing and the reconnection requirement, other trenchless technologies, such as sliplining, pipe bursting, or directional drilling were not attractive.

The multi-technique approach was cost effective and minimized disruption to customers and the road utility.

Case Study No. 3*Basic Problem:*

A medium-sized water utility has 1935 to 1945 vintage cast iron pipes of 150 mm and 200 mm diameters in a portion of its distribution system. The residents have been experiencing frequent episodes of red water over the last several years. They also have reduced pressure during certain times of the day. There appears to be few water main breaks and hydrant flow rates are low.

Causes:

The water main has internal corrosion but very little external corrosion and, thus, is structurally sound.

Outcomes:

The decision flow chart (Figure 4–1) was used in the selection of the best technology to use for rehabilitation or replacement.

Using their existing customer complaint database and supplementing with further flow analysis and non-destructive pipe testing, the problem was better quantified. This more in-depth documentation of the problem allowed them to follow the decision flow chart starting at the poor water quality path.

The chart led management to the non-structural and semi-structural rehabilitation box. Of the four alternative technologies identified on this path, the decision flow chart indicated that the best fit was the epoxy spray lining (non-structural).

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