SPEED AND QUALITY OF LINEAR SYSTEM REPAIRS

A BEST PRACTICE BY THE NATIONAL GUIDE TO SUSTAINABLE MUNICIPAL INFRASTRUCTURE

National Guide to Sustainable Municipal Infrastructure
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Speed and Quality of Linear System Repairs
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INFRAGUIDE – INNOVATIONS AND BEST PRACTICES

Why Canada Needs InfraGuide
Canadian municipalities spend $12 billion to $15 billion annually on infrastructure, but it never seems to be enough. Existing infrastructure is ageing while demand grows for more and better roads, and improved water and sewer systems. Municipalities must provide these services to satisfy higher standards for safety, health, and environmental protection as well as population growth. The solution is to change the way we plan, design, and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure: Innovations and Best Practices (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the National Guide to Sustainable Municipal Infrastructure (InfraGuide). InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: municipal roads and sidewalks, potable water, storm and wastewater, decision making and investment planning, environmental protocols, and transit. The best practices are available on-line and in hard copy.

A Knowledge Network of Excellence
InfraGuide's creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers, and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure, while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups — with the assistance of consultants and other stakeholders — are responsible for the research and publication of the best practices. This is a system of shared knowledge, responsibility, and benefits. We urge you to become a part of the InfraGuide Network of Excellence. Whether you are a municipal plant operator, a planner, or a municipal councillor, your input is critical to the quality of our work.

Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at <***www.infraguide.ca***> for more information. We look forward to working with you.

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Carl Yates, Chair	Halifax Regional Water Commission, Halifax, Nova Scotia
Fred Busch	Mayor, District of Sicamous, British Colombia
Sukhi Cheema	Government of the Northwest Territories
Normand DeAgostinis	Ductile Iron Pipe Research Association, Anjou, Quebec
Tim Dennis	Region of Halton, Ontario
Dave Green	Health Canada, Ottawa, Ontario
Raymond Leclerc	City of Montréal, Quebec
Piero Salvo	WSA Trenchless Consultants Inc., Ottawa, Ontario
Doug Seargeant	EPCOR Water Services Inc., Edmonton, Alberta
Ernie Ting	Town of Markham, Ontario
Michael Tobalt	Technical Advisor, National Research Council, Ottawa, Ontario

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Ken Brothers	Halifax Regional Water Commission, Halifax, Nova Scotia
Norm DeAgostinis	Ductile Iron Pipe Research Association, Anjou, Quebec
Brian Kellsey	EPCOR Water Services Inc., Edmonton, Alberta
Alex Marich	City of Toronto, Ontario
Francois Pothier	City of Sorel-Tracy, Quebec
Mark Robertson	City of Guelph, Ontario
Isabelle Tardif	City of Gatineau, Quebec
Ernie Ting	Town of Markham, Ontario

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Michel Aubé	City of Montréal, Quebec
Hans Kamping	Ontario Water Works Association (OWWA) – A Section of AWWA, Distribution Committee, Ontario

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Governing Council:

Joe Augé	Government of the Northwest Territories, Yellowknife, Northwest Territories
Mike Badham	City of Regina, Saskatchewan
Sherif Barakat	National Research Council Canada, Ottawa, Ontario
Brock Carlton	Federation of Canadian Municipalities, Ottawa, Ontario
Jim D'Orazio	Greater Toronto Sewer and Watermain Contractors Association, Toronto, Ontario
Douglas P. Floyd	Delcan Corporation, Toronto, Ontario
Derm Flynn	Town of Appleton, Newfoundland and Labrador
John Hodgson	City of Edmonton, Alberta
Joan Lougheed	City of Burlington, Ontario
Saeed Mirza	McGill University, Montréal, Quebec
Umendra Mital	City of Surrey, British Columbia
René Morency	Régie des installations olympiques Montréal, Quebec
Vaugn Paul	First Nations (Alberta) Technical Services Advisory Group Edmonton, Alberta
Ric Robertshaw	Public Works, Region of Peel, Brampton, Ontario
Dave Rudberg	City of Vancouver, British Columbia
Van Simonson	City of Saskatoon, Saskatchewan
Basil Stewart	Mayor, City of Summerside, Prince Edward Island
Serge Thériault	Government of New Brunswick, Fredericton, New Brunswick
Tony Varriano	Infrastructure Canada, Ottawa, Ontario
Alec Waters	Alberta Infrastructure Department, Edmonton, Alberta

Wally Wells	The Wells Infrastructure Group Inc. Toronto, Ontario

Municipal Infrastructure Committee:

Al Cepas	City of Edmonton, Alberta
Wayne Green	City of Toronto, Ontario
Haseen Khan	Government of Newfoundland and Labrador St. John’s, Newfoundland and Labrador
Ed S. Kovacs	City of Cambridge, Ontario
Saeed Mirza	McGill University, Montréal, Quebec
Umendra Mital	City of Surrey, British Columbia
Carl Yates	Halifax Regional Water Commission, Halifax, Nova Scotia

Relationship Infrastructure Committee:

Geoff Greenough	City of Moncton, New Brunswick
Joan Lougheed	City Councillor, Burlington, Ontario
Osama Moselhi	Concordia University, Montréal, Quebec
Anne-Marie Parent	Parent Latreille and Associates Montréal, Quebec
Konrad Siu	City of Edmonton, Alberta
Wally Wells	The Wells Infrastructure Group Inc. Toronto, Ontario

Founding Member:

Canadian Public Works Association (CPWA)

EXECUTIVE SUMMARY

This best practice serves as a road map for water utilities for planning and improvements related to the speed and quality of linear system repairs.

It must first be made clear that in the context of this best practice, the term "speed" does not mean "*how fast a watermain failure can be repaired*" but rather "*how quickly a watermain failure can be detected, located, and repaired using the highest standards for safety, quality, and efficiency*."

This best practice looks at the leakage run time aspect of watermain failures and at approaches available for improving the awareness, location, and repair times for watermain failures.

This paper also explores the importance of knowing how to respond to reported and unreported failures, and their effects on water loss and the water system. Appropriate failure-locating and pinpointing activities are also highlighted.

Major issues dealing with the repair of watermain failures include customer service, water quality, sustainability, economics, safety, and documentation. A general watermain failure repair methodology is presented to help water utilities prepare their own in-house procedures to ensure the quality of repairs.

All of these approaches give water utilities appropriate tools to allow continuous improvement, reduce of life cycle costs, enhance service life, protect the linear asset valuation associated with watermain failures, and determine how best to track these improvements.

1. GENERAL

1.1 INTRODUCTION

This document details the best practice for the speed and quality of linear system repairs. Its initiation followed the development of the InfraGuide's other potable water best practices, which include:

- Water Use and Loss in Water Distribution Systems;
- Deterioration and Inspection of Water Distribution Systems;
- Selection of Technologies for the Rehabilitation or Replacement of Sections of a Water Distribution System;
- Water Quality in Distribution Systems;
- Establishing a Metering Plan to Account for Water Use and Loss; and
- Developing a Water Distribution System Renewal Plan.

The above best practices address the water loss and linear system challenges and rehabilitation methods, but do not directly address the need for speed and quality of repairs for linear systems. This best practice addresses this issue.

It must first be made clear that, in the context of this best practice, the term "speed" does not mean "*how fast a watermain failure can be repaired*" but rather "*how quickly a watermain failure can be detected, located, and repaired using the highest standards for safety, quality, and efficiency*."

1.2 SCOPE

The objective is to give utilities a road map to the methods and technologies associated with awareness, location, and repair of linear system failures. The responsiveness to real losses (whether reported or unreported failures), the approaches used in locating failures, and the standard procedures for a repair of good quality are all addressed in this document.

The main purpose of this best practice is not to set standards for completing watermain repairs. Instead, it addresses the broader issues of awareness and responsiveness to linear system failures and the general approaches and requirements for completing a repair of good quality.

1.2.1 Links to Current Industry Best Practices on Linear System Repairs

The Canadian Water and Wastewater Association (CWWA), the American Water Works Association (AWWA), the American Water Works Association Research Foundation (AWWARF), and the International Water Association (IWA) are leading authorities in the water industry. Each organization provides valuable resources to water utilities and sets the standards from which this best practice was developed.

It must be noted that detailed information on standard practices for recommended repair methodologies for various pipe types and failure modes is not readily available from the sources listed above or from pipe manufacturing associations.

1.3 Glossary

District metered area (DMA) — A discrete area of a distribution system generally covering 25 km of watermain or 2,500 service connections with one or more metered inputs. It is used to calculate the levels of real losses.

Dry hole — Field term used by water system operators to define an excavation at a location where a water leak was suspected but was not found.

ICI — Industrial, commercial, and institutional.

Linear system — The buried linear infrastructure, which for water systems includes the piping, hydrant, and valving network. Linear systems do not include pump stations, storage production, or treatment facilities.

Real losses — Water that is produced and distributed, but is physically lost from the distribution system up to the point of customer metering or the property line if no meter is installed.

Reported failures — Watermain failures that are normally reported to the utility due to a visible surfacing of water.

SCADA — Supervisory control and data acquisition system.

Unreported failures — Watermain failures or leakages that are not visible at the surface and can only be found using proactive leak detection methods.

2. RATIONALE

In Canada and across the world, dealing with aging infrastructure is a growing concern and challenge. Increasingly, water loss and pipeline renewal issues challenge water distribution system managers and operators. Unfortunately, it is not physically possible to construct and operate a leak-free, failure-free water distribution system.

Many factors cause failure by affecting the distribution system materials and piping:

- pipe and fitting material;
- pipe and fitting manufacturing and quality control;
- pipe and fitting handling and storing;
- design and installation practices;
- traffic loading and vibration;
- soil and groundwater environment and corrosion;
- system pressures and transients;
- operational practices and maintenance;
- water quality and chemical characteristics; and
- proximity to and activities associated with construction, operation, or repair of other utility infrastructure.

Although several studies have been undertaken to identify and categorize watermain failures, no definite solutions have been established to ensure that they do not occur. In fact, it is not normally one factor but a combination of several of the factors listed above that ultimately causes a watermain failure.

Most often, these system failures start off as small, sometimes undetectable leaks, graduate to more severe problems, and finally result in an ultimate watermain or service line failure. Although leakage and watermain failures are unavoidable, there are ways to evaluate and control the level of system failures and water loss.

The IWA introduced a new concept dealing with controlling system water losses and leakage. Since no system can be constructed and maintained economically without leakage, the IWA has identified four water loss reduction components aimed at reducing actual water losses to the technical unavoidable minimum (AWWA, 2003).

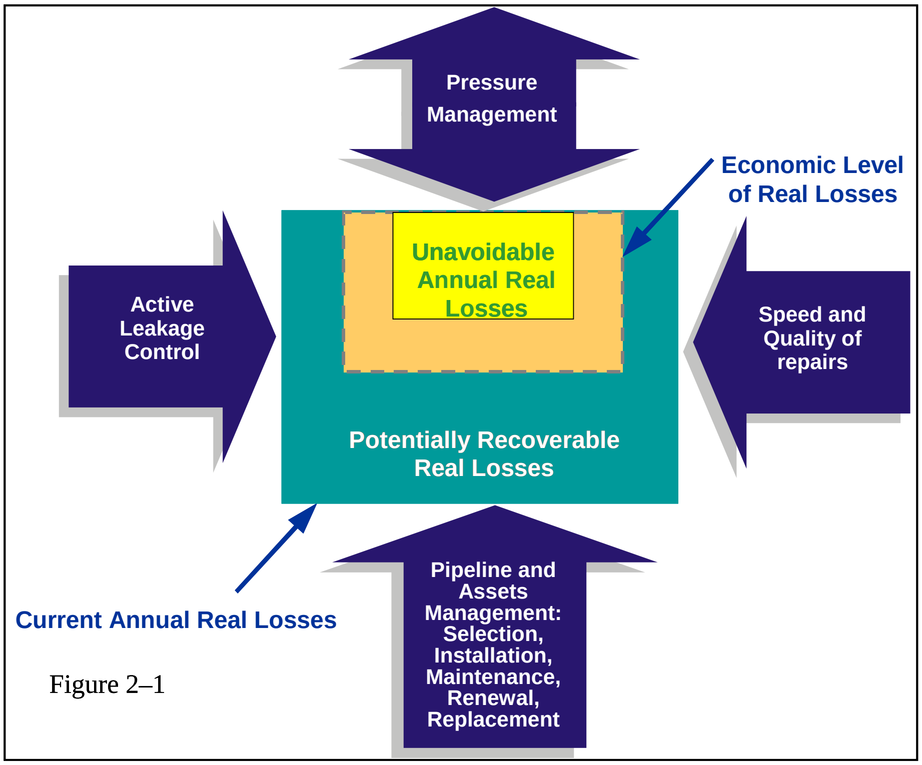


Figure 2–1: Water Loss Control Components

These four components include:

- speed and quality of repairs;
- infrastructure management;
- active leakage control; and
- pressure management.

These four components form the foundation of any best practice aimed at the optimal management and operation of a water distribution system. Although this best practice focuses on the speed and quality of the repair component, additional information on other components for reducing water losses can be found in the following InfraGuide best practices:

- Deterioration and Inspection of Water Distribution Systems;
- Selection of Technologies for the Rehabilitation or Replacement of Sections of a Water Distribution System;
- Developing a Water Distribution System Renewal Plan;
- Water Quality in Distribution Systems;
- Water Use and Loss in Water Distribution Systems; and
- Establishing a Metering Plan to Account for Water Use and Loss.

2.1 Reasons for Speed and Quality of Repairs

There are various reasons for ensuring that due diligence is used in the responsiveness and repair of linear system failures. The most apparent drivers include the following.

Water accountability: System failures equal lost water. Identifying the level of losses in a system and quickly locating them will help reduce losses and conserve a precious resource. Often, system operators only react to noticeable water losses. In other words, they take a passive approach. However, by using a more proactive approach to loss control, the occurrence of larger watermain failures will be decreased and costly repairs avoided.

Reliability of supply: Water outages are generally unavoidable when repairing watermain failures. Quickly identifying and locating watermain failures can help avoid more severe failures. This will help to reduce the service disruption required for more detailed and costly repairs that may include the need for specific disinfection processes or temporary servicing.

Customer service: Watermain failures and water outages may result in poor customer relations. Proactively identifying failures before they become critical allows system operators to plan appropriately for repair and customer notification. Customers expect and deserve a high level of service. With appropriate measures, operators can manage the magnitude and severity of problems associated with emergency watermain failure repairs.

Infrastructure renewal: Watermain failures can lead to excessive capital expenditures, increased life cycle costs and reduced infrastructure life. Proactive identification of water losses and watermain failures at an early stage will help extend the service life of the piping infrastructure and reduce social costs. In addition, with appropriate record keeping, problem areas can be quickly highlighted for effective rehabilitation planning.

Water quality: Each watermain failure poses a potential contamination threat. Ensuring that the right people have the right training, the right tools and materials, and finally the right procedures will ensure a fast, reliable, efficient, and safe watermain repair that will not compromise water quality.

Public and staff safety: Maintaining public and staff safety during watermain repairs is of utmost importance. Public safety from the time the failure is first identified is also a concern. In sub-zero conditions, freezing water on flooded streets can quickly become a safety and potential liability issue. Keeping the work area safe and following appropriate procedures and standards during a repair will ensure the quality of the work and the safety of both the workers and the general public. Since most repairs involve excavation in the road right-of-way, appropriate traffic control procedures and communications are important. Several available manuals address proper roadway safety set-ups.

Increased awareness: By increasing the quality and level of monitoring in a system, operators will quickly become more aware of problem areas with possible watermain failures. Using DMAs or existing SCADA networks to monitor night flows will help identify failures before they become more serious.

Quality of locates: Ensuring that failure locations are identified quickly and accurately will greatly improve the speed and quality of repairs. Using the appropriate procedures, techniques, and equipment, coupled with properly trained staff, helps to pinpoint failures quickly and accurately. Enhanced locating procedures reduce costly excavation and limits construction disruption to customers.

Protection of **property and the environment:** Each watermain failure poses a potential for damage to both public and private property as well as to the environment. Roadway degradation and undermining, discharge into waterways, storm and sewer damage, property flooding, and sewer backups are a few examples of potential damage. Proper responsiveness and repair techniques in response to linear system failures can mitigate this potential for damage.

The following sections of this best practice elaborate on these issues and suggest appropriate measures to enhance the speed and quality of linear system repairs.

3. Strategies for Improving the Speed of Linear System Repairs

It should again be emphasized that, for this best practice, the term “speed” does not refer to how fast one conducts the actual watermain repair, but rather how quickly one is made aware of, responds to, and locates a watermain failure.

This section deals with “speed” or responsiveness. Three important components affect the speed with which linear failures are identified, located, and repaired.

Awareness: How quickly is one made aware of a watermain failure? Awareness is most often overlooked, but is the most crucial aspect in reducing leakage run times, water loss, and associated social and damage costs.

Location: How quickly and accurately is a watermain failure pinpointed and identified for repair once it has been reported?

Repair: How quickly and effectively is the repair crew dispatched to repair the failure once it is has been pinpointed?

3.1 Improving Awareness Response Time

To identify the appropriate measures to improve the awareness of water failures, it is important to highlight different types of failures and their effect on awareness, leakage run time, and water loss.

There are two types of watermain failures: reported and unreported.

Reported failures are traditionally known as “watermain breaks,” where water quickly bubbles up at the ground surface and, in some cases, washes away parts of the roadway. These failures are classified as reported, meaning that consumers, utility staff, or others will quickly see and identify them and report into the water operations centre for action. In addition, customers often report service failures after hearing a “whistling” noise in their water pipes. The awareness time for this type of leakage is normally relatively short.

For example, a watermain failure occurs on a 300-mm-diameter watermain and surfaces in the shoulder of a roadway. It is flowing at a rate of 500 l/min and is observed and reported to the water operations centre by local residents. A crew is immediately dispatched to the location. The total awareness time for this failure is, on average, less than 24 hours. Assuming 18 hours as an awareness time, a total of 0.54 ML of water was lost in leakage.

Unreported failures do not surface, and water escapes into the ground without any visible signs of leakage observed at the ground surface. These failures may have a long awareness time if routine measures to identify them are not implemented. Over time, these failures tend to become more severe and may eventually become a reported failure where substantial damage to the surrounding environment may have already occurred. Unreported leaks can easily run for weeks, months, and even years causing substantial water and revenue loss and unknown costs with damage to both the road structure and adjacent infrastructure.

For example:

Reported Failure
A failure occurs on a 300-mm-diameter watermain and surfaces in the shoulder of a roadway. It is flowing at a rate of 500 l/min and is observed and reported to the water operations centre by local residents. A crew is immediately dispatched to the location. The total awareness time for this failure is on average less than 24 hrs. Assuming 18hrs as an awareness time, a total of 0.54 ML of water was lost in leakage.

Unreported Failure
A failure occurs on a 150-mm-diameter watermain and the water leaking from the broken main is escaping into the sanitary sewer system. It is flowing at a rate of 150 L/min. There is no sign of leakage at the ground surface. It is not identified as a leak until the utility maintenance staff's next routine maintenance and sounding of fire hydrants, some three months later. Therefore, the total awareness time for this failure is about three months. Assuming an awareness time of 90 days, a total of 19.44 ML of water was lost in leakage. In addition, the leaking water was also discharged into the sanitary system, requiring subsequent treatment.

This example shows how unreported failures can have a substantial effect on water loss and how effective awareness programs can help reduce water loss and leakage run times, highlight potential damage to other utilities and the road structure, and identify costs and watermain failures before they become catastrophic.

3.1.1 Reported Failure Awareness

Since reported failures are normally seen and called in by individuals, the most effective way to reduce awareness time is to educate the community, staff of other utilities, and municipal workers in the signs of failures, including making sure they are aware of the appropriate contact numbers for reporting the failure. The following approaches can be considered.

Engage the General Public

- Use the local media to inform and educate the public about the water system and its operations.
- Provide literature to promote awareness of watermain failures, including contact information or a hotline number.
- Include a regular newsletter or brochure with the water bill.
- Provide information on the consequences of letting a leak run for extended periods of time (i.e., social and damage liability, water quality, costs).

Engage Municipal and Other Utility Staff

- Educate staff in all municipal departments (wastewater, transportation, parks and recreation, fire, and transit) or in other utilities (gas, power, telecommunications, and cable), who routinely encounter the system, to be on the lookout for signs of water leakage.

Engage Other Groups

- Taxi cab drivers, private security patrols, police, night watch groups, delivery companies, and others can all be contacted and provided with information on the signs of failures and contact information for reporting failures.

In essence, educating and engaging individuals is key in reducing the awareness time for reported failures.

3.1.2 Unreported Failure Awareness

Leakage detection is an important component of an overall water loss program. Reducing the unreported failure awareness time requires a more proactive approach and, in most cases, a new management approach to water loss control. In essence, the average awareness time of unreported failures can be estimated at one half of the total amount of time between interventions. The following provides the various interventions available for detecting the presence of unreported failures. For further information on water loss control, please refer to the InfraGuide best practice, *Water Use and Loss in Water Distribution Systems*.

Water Balance

The completion of a water balance over a rolling 12-month period will help assess the level of real losses in a distribution system. Analysis of the water balance will give staff a method for evaluating the costs of unreported failures, and a potential way to recover related leakage. If a system has never completed any level of unreported failure detection, it is recommended that an initial 12-month water balance exercise be undertaken to assess the level of leakage and the level of intervention required. Once a water balance is in place, a rolling 12-month water balance (last month out – new month in) will help track and identify potential new failures on a system-wide basis.

Acoustic Leak Detection Surveys

Acoustic leak detection surveys have been used for over 100 years as the primary method for identifying and locating unreported failures. Staff is deployed with leak detection acoustic devices and leak noise correlators in a survey mode to detect unreported failures. Leaking watermains vibrate and transmit noises that are audible using appropriate equipment. Surveying and listening to every available fitting on a water distribution system and mapping potential leak noise for further investigation is an effective approach for detecting unreported failures. It must be noted that this methodology has its limitations on non-metallic piping networks. In addition, completing an acoustic leak survey does not ensure that all unreported failures have been identified and located. After an acoustic survey, when calculating the water loss from unreported failures, use an average awareness time of half the frequency of the survey (i.e., a six-month awareness time for yearly acoustic surveys).

Distribution System Metering

With the advent of SCADA systems and distribution system metering, it is easier to track water moving through a distribution system. For smaller systems, production or source meter readings can be tracked for apparent changes in production volumes or minimum flow rates. In larger systems with bulk metering between pressure zones, water volume and demand can be tracked, and significant changes can be investigated further. Distribution meters can help to identify when more detailed intervention methodologies may be beneficial.

District Metered Area

These specifically controlled areas of a distribution system are used to evaluate the actual level of real losses on a continuous basis. This is achieved by using district meters that log or report minimum nightly flows, and are assessed on a continuing basis to track even small variations in nightly flow rates. District metered areas are among the most effective tools to control and reduce the awareness time of failures, and also to control the actual levels of real losses within an economic level. By comparing minimum nightly flows on a daily basis, it is possible to assess the level of change in flows that warrants detailed leak investigation (i.e., sonic leak survey).

Although several methodologies have been demonstrated in this best practice for reducing the awareness time for both reported and unreported failures, each utility should complete a cost evaluation of its leakage losses to determine the appropriate level of intervention. Most often, a combination of some or all of the various methodologies provides the most economical and effective approach.

3.2 Improving Location Response Time

Once the utility has been made aware of a failure (either reported or unreported), the actual location of that failure must be pinpointed before dispatching repair crews.

Again, the type of leak often dictates the response of the leak-locating activities. Reported failures are often given a very high priority due to their nature, visibility, and potential risk of damage and associated claims. Unreported failures identified through active leak detection are normally lower on the priority list depending on the magnitude of leakage, criticality to the water system, and the possibility of associated damage. Identified unreported failures can also contribute to significant water loss. By delaying leak-pinpointing activities, excessive volumes of water may be lost, other utilities and road structures may be damaged, and social costs may occur.

To minimize intended and unintended costs associated with water loss and reduce leakage run times to a minimum, consider the following proactive approaches for improving the speed of locating linear failures.

- Track and prioritize each failure when reported.
- Assign specific staff to pinpoint the failure.
- Use the latest techniques in leak detection and pinpointing equipment, such as leak noise correlators, acoustic sticks, and ground microphones.
- Train staff to use the leak detection equipment properly.
- Ensure that failure locating staff have access to the latest asset information and system mapping in the field.
- Request and record utility locates for water and other utilities, such as gas, power, telecommunications, and cable.
- Prepare a detailed report to ensure that repair crews can identify the exact failure location.
- Rate the level of severity of the failure to prioritize repair crews.
- Assess the probable type of failure to ensure repair crews prepare the appropriate materials and equipment needed for the repair.
- Identify critical customers within the repair area that may be impacted and communicate and co-ordinate the repair with them.
- Identify required line valves needed to isolate the failures, if required.
- In addition to the approaches listed above, it is good practice to complete pinpointing activities for all watermain failures, whether they were identified as a reported or unreported failure. Pinpointing a failure within one excavation has obvious economic and social benefits. By employing state-of-

the-art leak detection equipment and properly trained staff, dry holes can be greatly reduced.

3.3 IMPROVING REPAIR RESPONSE TIME

The time it takes to dispatch a repair crew following the pinpointing stage also greatly affects the leakage run time and water loss. The failure type, location, and reported severity will the repair.priority (i.e., a large failure will be repaired before a water valve packing leak). Other factors that affect failure repair prioritization include:

- watermain use (i.e., trunk or arterial watermain);
- affected customers (i.e., residential, industrial, commercial, or institutional);
- requirements for provisional supply;
- ability to obtain other utilities' locates and clearance forms quickly;
- impact of failure on adjacent properties;
- crew availability and overtime costs; and
- other community disruption considerations, such as traffic flow impediments.

However, it must be noted that prioritizing failure repairs should include an evaluation of water loss to ensure that repairs are quickly completed, as highlighted in the following examples.

Watermain failure: A watermain failure is identified and pinpointed on a 150-mm watermain. The average flowrate is 100 L/min. The repair is scheduled but not completed for two days. The water loss associated with the repair time is 0.29 ML.

Utility side service failure: A water leak has been identified and pinpointed on the utility side of the service lateral to a residence. The average flow rate is 12 L/min. The repair is scheduled and completed within two weeks. The water loss associated with the repair time is 0.24 ML.

Private side service failure: A water leak has been identified and pinpointed on the private side of the service lateral to a residence. The average flow rate is 12 l/min. The repair is the responsibility of the property owner and is not scheduled and completed for six weeks. The water loss associated with the repair time is 0.73 ML. It should be noted that many municipalities do not have any recourse for requiring private property owners to repair their leaking water service laterals unless it has an environmental impact. Some utilities have drafted bylaws stating that the water loss from a leaking service lateral has an environmental impact of wasting water and imposing a timeframe for repair.

As this example illustrates, every failure should be repaired quickly to minimize leakage run times and reduce water loss. It is not uncommon for service lateral repairs to be low on the priority list. It is important to note that small leaks running for a long time waste more water than large leaks that are repaired quickly.

4. STRATEGIES FOR IMPROVING THE QUALITY OF LINEAR SYSTEM REPAIRS

Ensuring the quality of linear system failure repairs should be a high priority for all water utilities. The key factors that must be considered when completing watermain failure repairs are:

- public and worker safety;
- water quality and public health;
- proper equipment and material selection;
- quality assurance and quality control practices;
- customer service and sustainability;
- community disruption and associated costs;
- proper training and procedures;
- proper data collection and management; and
- cost and environmental impact minimization.

The following sections highlight how to address these key factors, and present a detailed general approach to improve the quality of repairs and develop a standard repair methodology.

4.1 IMPROVING THE QUALITY OF REPAIRS

The following broad approaches should be considered to ensure the quality of linear system repairs.

4.1.1 Safety

Ensuring that proper procedures are in place for public and worker safety during repairs is critical. Such aspects as traffic control, site set-up, public notification, essential service notification, equipment selection, trenching, and utility locates must be considered. It is imperative that all staff receive the proper safety training needed to complete watermain repairs. Local health and safety regulations must be followed and a health and safety committee formed within the utility to ensure that all aspects dealing with safety are considered.

4.1.2 Water Quality

Each linear system failure is a point of potential contamination. Appropriate measures should be adopted to ensure that water quality is never compromised during the repair process. There can be various procedures for different types of watermain failures. However, certain aspects should always be implemented:

- working under positive water pressure when possible;
- proper cleaning and disinfection of the repair area, as well as repair materials and equipment;
- proper testing, flushing, and disinfection procedures for watermain recommissioning; and
- appropriate water quality sampling and results recording.

It is important to follow all provincial regulations dealing with water quality and monitoring procedures at all times. In addition, implement the recommendations of ANSI/AWWA Standard 600-93 (cleanliness of pipe, fittings and appurtenances) and AWWA Manual 20, Water Chlorination Principles and Practices.

4.1.3 Proper Training

Ensure that repair crews are properly trained in all aspects of the work and have the appropriate equipment and materials to complete the work. Not all provinces and territories require licensed (certified) water system operators for completing watermain repairs. If the repair crew members are not certified, at least one qualified worker should be present for the duration of the work.

4.1.4 Documentation

All aspects of a watermain failure should be documented, including the awareness, location, and repair parameters. The information can be used for quality control and quality assurance tracking, and for total failure cost evaluation. Information that should be collected during a watermain repair includes location, type of failure, pipe information (repair materials and methodology), testing results (pressure and water quality) and, if possible, pipe and soil sampling to help assess the cause of the failure.

4.2 General Repair Methodology

Each water utility should develop for field crews a procedure manual outlining general repair practices to be used during a watermain failure repair. Many larger utilities have developed such manuals in great detail. The following section is not an official procedure manual, but a guide for utilities in the development of a procedures manual. It also helps water utilities that have developed a procedure to cover as many aspects as possible. Some provincial jurisdictions have legislated the need for water distribution operations and maintenance manuals.

In addition to the following general repair methodology outline, Appendix A contains a flow chart of activities required during a watermain failure repair. It was graciously provided by the City of Ottawa and is part of their *Water System Operation and Maintenance Manual*.

Please note that the general repair methodology outlined below is presented as a response to a reported failure. However, most of the material provided can be easily applied to any failure situation.

Dispatching Repair Crew
■ Ideally, the water authority should respond with a crew within one hour of a reported failure. Response time should not be adjusted, because of reports that the failure appears to be minor. Some ground conditions give little indication of the real damage being done beneath the surface. ■ Crews and supervisors should be outfitted with portable radios that permit unimpeded communication. ■ It is recommended that all dump trucks, flatbed delivery trucks, tractors, and excavators be equipped with vehicle-mounted radios. This helps to assure that someone at the repair site can be reached at all times.
Repair Site Preparation
■ The crew should quickly assess the general location of the failure, and then position a vehicle up-traffic of the failure as the first step to securing the site. ■ This vehicle should be equipped with a rotating beacon, traffic arrow, or any combination that permits it to stand out in the roadway. In addition, all crew members should be wearing appropriate protective and reflective clothing. ■ If the crew is fairly confident that the failure will be close to where the water is emerging, calls for utility locates and trenching permits should be made as soon after arrival as possible. ■ Traffic cones and warning signs should be quickly spread out before, across, and beyond the repair site. All traffic gear should conform to the requirements of the road authority, and set up in a manner that agrees with the requirements of the traffic field handbook, distributed by the Ministry of Transportation. ■ Flooding from the site should be controlled. Water should be directed to nearby street catch basins. Sediment control measures should be put into effect in accordance with local bylaws to protect the local sewer system and surface waters. ■ If the crew is working in frozen conditions, they should contact the road authority to lay sand and salt down around the failure area, and on streets that may have been iced over by initial floodwaters.

Notification of Customers

- Often, in the event of an emergency repair, little warning can be offered to consumers that the water is going to be turned off. Nonetheless, soon after arrival on site, the crew should consult water system maps, and determine the watermain sections that should be isolated to repair the failure.
- Crew members not occupied in failure detection or watermain turn-down should then start out on foot to knock on every door within the isolation route to inform residents that the water will soon be turned off. Residents should be encouraged to draw water for drinking, cooking, and sanitary disposal as quickly as possible.
- Some water authorities may choose to leave an emergency water repair pamphlet, with the phone number of the water department, at homes where there is no response.
- The notification crew must be vigilant for sensitive and critical water users.
- The presence, along the route, of such facilities as hospitals, medical clinics, industry, schools, homes for the elderly, daycare centres, restaurants, and bakeries, should be brought to the immediate attention of the repair supervisor. Based on such findings, there may be a need to delay final isolation of the water supply, or make alternative water supply arrangements.

Notification of Essential Services

- The fire department must be given advanced notice of which fire hydrants are going to be affected by a watermain shutdown. Tagging of these hydrants is recommended.
- As soon as the crew begins to shut valves to throttle the route, the water department dispatcher, or the repair supervisor, should contact the fire department communications centre to inform it that a section of the water system is being shut down.
- Assure the fire department that they will be informed as soon as the repair is complete, and the water system returned to normal.
- Ambulance, police, and transit services should be notified that traffic flow has been restricted in the area of the watermain repair. If the repair requires total road closure, this information becomes vital to all services.
- The traffic department should be notified for two reasons. It must be able to answer questions that will come from the public about delays. It may also be able to offer assistance in directing traffic through the affected area, possibly helping to set up a detour route, if required.
- Within the water department, the dispatcher or customer service section, should be given some details of the nature of the repair, including the number of streets affected by the water outage, the traffic restriction along the street, and the estimated time of repair, if that can be offered.
- Failures that have created significant damage, that occur in water-sensitive areas, or that create large traffic diversions, should be brought to the immediate attention of higher levels of management within the water department. These officials can help to authorize and co-ordinate more resources to the repair site, and field questions from politicians and the media.

Isolating the Repair Section
■ Once traffic gear has been set up around the repair zone, the damaged road section made safe, and the failure location determined, the crew can begin shutting and throttling water valves. A careful documentation of which valves are involved in the shutdown is highly recommended. This will allow a systematic method of returning the water system back into service. It is also recommended that 4 or 18-litre potable water containers be available to staff for distribution to affected customers should the need arise. ■ Some co-ordination must take place so the last valves are not shut until affected residents have had time to draw water. ■ The repair crew must make the decision to either throttle or shut the main completely. On most failures, crews should attempt to “work wet” by excavating and repairing with a small measure of pressure remaining in the watermain. Some valves may be shut fully, but one or two may be adjusted so the volume of water is low enough that water emerging from the failure is manageable by pumps, cannot soak or injure workers, and does not impede repair measures. Working wet prevents back flow from elevated water services within the shutdown area, and prevents contaminant entry at the repair site. ■ Working with a reduced flow in the watermain works well in the many cases involving circumferential failures. However, any repair that calls for the cutting and removal of a section of water main will require full isolation and drainage of the pipe section to accomplish the repair. ■ Some failures create huge road upheaval and extensive flooding, resulting in traffic hazard and property damage. Severe failures that present this kind of scenario must be isolated as quickly as possible, with the main shut off completely. There will also be no time to notify residents along the shut down route, except after the fact.
Excavation Over the Watermain
■ If the watermain is located under the roadway, curb, or sidewalk, saw cutting should be used to minimize the damage to the surrounding area. ■ The excavator should be directed to dig initially on the side of the main that is clear of services, and should be cautioned to not come any closer than one metre of where the watermain is thought to be located. ■ Once close to the watermain depth, the main should be finally located by hand using a shovel or probe bar. Excavators should be discouraged from locating the pipe by pawing for and touching the main. ■ When the watermain and services are finally exposed, the excavator can be safely directed to dig closer to complete and square off the excavation. ■ With the failure exposed, the crew may decide to close any partially open valves even further, if the flow is interfering with the repair. ■ The size of the excavation should be such that portable trench box systems, if required, can be lowered into place. ■ The excavation should be roughly centred on the failure, and deep enough that the watermain is fully exposed and clearly suspended in the trench, with at least 300 mm between the pipe and the base of the trench. ■ As a final measure before the shoring is established, crews should spread 100 mm to 150 mm of clear stone across the bottom of the trench. This will provide

good footing for the crew and will help maintain sanitary conditions throughout the repair.

- If the crew encounters any evidence of contaminated soil during excavation, the supervisor should be immediately notified, and the appropriate representatives of the provincial or territorial environment department summoned to the site. All activity should cease on the site, while proper procedures are put in place to protect the workers, the water system, and the environment.

Shoring

- Guidelines of the relevant provincial or territorial occupational health and safety act must be closely followed. They describe requirements of anyone preparing to enter a trench or excavation that is at a depth of 1.2 m or more.
- Apart from the shoring guidelines mentioned in the Act, the Ministry of Labour has approved several portable shoring systems that can be lowered into place and secured in the excavation.
- Trench boxes, or portable build-a-box systems, must be lifted and manoeuvered by equipment that is suited for the task.
- It is worth stressing that the worker must be protected from the collapse of all four walls of the trench.
- When the crew puts any shoring mechanism into place, the weight of the mechanism must not be borne by the watermain.
- The shoring box, or device, must rest fully on the bottom of the excavation. Secure its base so it will not move if a wall collapses.
- No contact should be permitted between the shoring device and the water pipe.
- No worker should be in the hole when shoring boxes are being lowered into, or raised from, any excavation.

Watermain Repair

Because there are so many different water pipe and service materials, and because they can fail in so many different ways, there will be no attempt to document the preferred repair methodologies for all failures.

Most water authorities already have useful maintenance standards that document how to successfully undertake repairs. However, apart from describing the actual repair technique, there are some observations worth highlighting.

- Water repair crews should be trained in, and must adhere to, the guidelines of the applicable occupational health and safety act.
- All required personal must wear protective equipment when and where appropriate.
- The excavation must be treated as a confined space. Repair crews must adhere to confined space entry/exit protocols.
- Any use of gas-powered equipment (or application of chemicals, such as sodium hypochlorite) in the trench must be accompanied by the use of a suitable mechanical air ventilator to ensure safe atmospheric conditions throughout the excavation.

- De-watering pumps must be positioned so their exhaust gases do not find their way into the excavation.
- Water repair crews must observe the information contained in ANSI/AWWA Standards 600-606, which address pipe installation procedures, guidelines on inspection, trench construction, joint assembly, flushing, and pressure and leakage testing.
- Repair crews should be informed of, and adhere to, all recommended uses and modes of application of water pipe repair parts, as recommended by the part manufacturer.
- Water repair crews should work in accordance with the recommendations of ANSI/AWWA Standard 600-99 for ductile-iron pipe applications.
- Crews must follow the repair site disinfection recommendations outlined in AWWA Standard C-651-99, the applicable provincial/territorial regulations, or those outlined in the water utilities guidelines and procedures. Care must be taken when discharging chlorinated water into ditches and sewer systems due to potential negative impacts on water courses.
- Repair crews must be aware of and protect the water system from contaminant entry that can be brought about by repair activities.
- Crews must separate tools used for wastewater repairs from tools used for water system repairs.
- Crews that conduct wastewater system repairs as well as water system repairs must arrange for their outer work clothing to be laundered frequently. The bacteria that can gather on clothing worn during a sewer main repair, or even during a sewer manhole entry, can contaminate exposed water pipe and repair fittings. Separate gloves should be worn by staff when switching from sewer to water repairs to reduce the potential for contamination of the potable water system.
- Crews must monitor and control vehicular and pedestrian traffic close near the repair site. They must see, first, that the traffic set-up is working as designed, and that no cones or signs are moved, or fall down, during the repair.
- The repair effort must continue, uninterrupted, until the pipeline is reassembled. The pipeline and the repair site should be attended at all times, to prevent third-party injury or vandalism, and to prevent possible further contamination of the exposed, and vulnerable, watermain.
- All damaged pipe sections, and fittings, should be removed from site. No scrap metal, or unsanitary debris, should be left in the excavation.
- All pipe materials and fittings used in the repair of water pipes should be of a similar diameter and material to the water pipe under repair. Failing that, the repair materials employed should be of at least the same pipe class and pressure rating, and be capable of handling the same operational conditions as the original pipe.
- All pipe lubricants used during repairs must be certified to meet the requirements of ANSI/AWWA and NSF/ANSI standards for materials.
- The lubricant must be non-toxic and water soluble, with no deteriorating effects upon gasket materials. It also should not impart any taste or odour to the water in the pipeline, nor support bacterial growth.
- As a final measure, corrosion of the repair fittings and the exposed watermain

should be controlled, if applicable. Several products on the market act as sacrificial devices and can be attached to the repair assemblies. Paraffin-impregnated pipe wraps are also a good corrosion deterrent. Zinc, or magnesium anodes can also be thermo-welded to the watermain, or metallic appurtenances can be installed with non-metallic piping. These protect the surface of the pipe against further corrosion for many years. The anode-welding kits are simple to use, and make it easy for any repair crew to apply spot cathodic protection.

Testing the Repair

- In returning the watermain to service, the crew will follow established main filling, flushing, and disinfection procedures.
- Normally, that means slowly feeding water back into the main from a low-elevation valve, and forcing air out of the system from the hydrant that is at the highest elevation of the isolated section of pipe.
- When the air appears to be vented, the feed valve can be opened a few more turns to power the watermain up for flushing.
- The crew will flush the watermain until the water appears clear, and will test for chlorine residual, turbidity, and water quality in both directions around the main repair.
- Crews must provide for proper disposal of chlorinated water. It is important for crews to be aware of any potential impacts on water courses.
- Once the watermain is flushed and back to normal operational pressure, the crew should closely check the repair to see that the pipe repair is dry and watertight. Sounding of the repair pipe will ensure that no other leakage is present within the repair area.
- At this point, some utilities may choose to notify all who were contacted earlier that the watermain is back in service or delay that call until the excavation is backfilled and compacted. Old cast iron water pipes have been known to fail again under normal compaction vibration.

Documentation

- Before backfilling, the crew should make some brief notes that describe:
  - the time the failure was dispatched to them;
  - the time the watermain was shut down;
  - the valves that were shut down to effect the repair;
  - the valves that were opened to put the watermain back into service;
  - the time the watermain was placed back into service;
  - the size and outside diameter of the main;
  - the depth of the pipe;
  - the road surface (concrete, asphalt, etc.);
  - an accurate location of the failure;
  - the nature of the failure (hole, split, circumferential break, etc.);
  - the appearance of the surface of the watermain (soft, ulcered, etc.);
  - some description of the soil conditions (clay, sand, mixed loam, etc.) in which the water pipe was laid;
  - measures taken to disinfect parts, fittings, and the repair site;
  - appearance of flush water, and how long it took to come clear when the main was reactivated;
  - any poorly performing or broken valves encountered during isolation;
  - any poorly performing fire hydrants encountered during the repair;
  - any other utilities encountered in the excavation; and
  - any damage done to nearby utilities during excavation.

In addition:

- If the repair required the removal of a section of pipe, that pipe could be sent to a materials testing laboratory for metalurgical testing that could determine the cause of failure.
- Soil samples should be gathered from the excavation, ideally from the watermain depth, and carefully assessed for its corrosive characteristics. This would help explain any external corrosion noticed on the pipe surface or other metallic appurtenances.
- The water authority should create a data acquisition document that should be fully filled out at every repair site.
- Repair excavations are ideal laboratories for gathering information that can only be acquired by actually unearthing the pipe. This information will aid in forecasting a remaining life for this section of watermain and help in the development of a water distribution system renewal plan.

See Appendix B for an example of a watermain repair field data sheet.

Restoration of Excavation
■ Following successful repair and inspection of the watermain, the shoring can be removed from the trench. Care should be exercised that the lift-out is clean, and that the pipe is not struck during removal of the shoring. ■ Regardless of the size of the watermain, and the nature of the repair, crews should backfill, compact, and restore excavations according to the best recommendations of the local road authority. They should follow the directions of their water system design section to safeguard the potable water supply system. Reference to InfraGuide Roads and Sidewalk best practice entitled "Restoration and Repair of Utility Boxes in Pavement" may also aid in attaining a successful excavation restoration. ■ Improper compaction often leads to subsequent pipe failures at the same repair site, because of uneven or improper support of previously exposed pipe. ■ Water system authorities can learn much from the manufacturers of potable water pipe regarding acceptable installation, bedding, and compaction for their individual products. There are differences in pipe material, and different methods of installing and compacting each material. As a general guide, these simple observations can assist in a well-restored excavation. ■ Select a backfill aggregate that most closely matches the material that is common throughout the rest of the water trench. ■ If the original trench material is hard to duplicate, a backfill aggregate that resembles a combination of fine (0.12 mm to 0.20 mm) stone and coarse sand will act as a suitable alternative. ■ The use of dry, loose, non-frozen aggregate is preferred. ■ The aggregate should be evenly spread beneath the entire section of exposed pipe. ■ There should be no voids in the support beneath the pipe. ■ Any water or other utility services that cross the excavation should be well supported from beneath, and covered by at least 300 mm of aggregate, before any vibratory compaction is applied from above. ■ When the aggregate is evenly spread to within about 900 mm from the lip of the trench, a portable compactor should be lowered, on a sling, into the excavation, where a crew member can evenly compact the area on each side of the pipe. ■ The area along the side of the pipe should be compacted first to firm up the bedding beneath the pipe and to support the haunches of the pipe, preventing lateral deflection. ■ Repair crews will likely have no way to measure the oft-quoted, and preferred, 95 percent Standard Proctor degree of compaction. However, a safe guideline is to watch the yield of the aggregate being compacted. Once there is no further collapse of the aggregate under the compactor, it can be assumed that the material is sufficiently compressed, and the compaction adequate. ■ The area of initial compaction should extend from the base of the excavation to

about 600 mm above the pipe and services. Once that area has been compacted, final compaction can get underway.

- Final compaction should be accomplished in appropriate lifts. Thickness of layers of material to be compacted will vary with the type of material and the degree of compaction required. The crew member and the compactor should be removed from the hole while another layer of aggregate is placed and spread evenly. It is important to ensure that material is placed evenly on both sides of the pipe to avoid stresses on either side of the pipe.
- The crew member and compactor can enter again, and should work the material until its compression seems complete again. This method of compaction should continue until the compacted material is level, and within 75 mm of the lip of the excavation.
- The edges of the cut should be cleaned and chipped, if necessary, to provide a good adhesive contact surface for the cold, or hot, patching material that will follow. Some jurisdictions may have utility cut repair requirements that must be followed.
- The last stage in the temporary repair to the road surface is to cap the site with a compacted 75 mm layer of tar-stone patch. Cold patch or hot patch should be evenly spread and compacted to provide a smooth travel surface that matches the grade of the road at the excavation.
- The final restoration process should follow the recommendations of the local road authority. Reference to the InfraGuide Roads and Sidewalks best practice, “Restoration and Repair of Utility Boxes in Pavements,” may prove beneficial.
- If the excavation is properly restored, there is a low probability of a new failure at the same site. There is also a greater likelihood that the restoration will hold up to traffic and weather conditions until a final restoration can be scheduled.

Recommissioning of the Watermain

- All valves that were used to isolate the damaged pipe section must be re-opened before the crew leaves the site. Opening all valves returns the system to normal flow velocity and operating pressure. A check list of closed/open valves is highly recommended.
- Once all valves are open, a final check should be made at nearby hydrants to ensure that the system is free of air, and that the water is clear.
- At this point, the system can be reported as fully pressurized and back to normal operational status.
- All local authorities notified at the onset of the repair procedure should be renotified that the system is back in service.

5. APPLICATIONS AND LIMITATIONS

5.1 FAILURE COST ASSESSMENT

For all water utilities, minimizing operational costs without compromising water quality, performance, and customer service levels is vital. This best practice has provided the basis for addressing all aspects of linear system failures. The purpose of the methodologies for improving the speed and quality of repairs was to identify areas for cost minimization.

Each utility should track its operational costs associated with various activities, including linear system repairs. However, all costs should be assessed in the evaluation to view the true cost of each failure.

Often, only the labour, equipment, and material costs are considered when tracking watermain repairs. For a true evaluation, all of the following costs must be considered:

1. **Cost of water loss:** An attempt should be made to calculate the total leakage run time and flow rate of each repaired failure. This includes assessing the awareness, location, and repair times. Most often, the water loss is priced at the marginal production cost of water. However, in areas where system capacity has been reached, the retail cost of water is often used.
2. **All labour and material:** All labour and material costs should be considered, including detailed leak detection activities used for identifying unreported failures, the locating exercise used for pinpointing, and the actual watermain repair activities.
3. **Environmental impact:** Include potential costs associated with the impact on the environment. Severe watermain failures can have serious impacts on the surrounding environment. These costs should be evaluated.
4. **Social impact:** Also include costs associated with the social impact to local customers during a watermain repair. This can be assessed by allocating appropriate values based on length of time of water service interruption and length of time for repair.
5. **Economic impact:** Similarly, assess and document the economic impact to local business during a failure. This may include damage claims, damage to road infrastructure, road cut permit cost, road deterioration costs, storm sewer damage or sedimentation costs, traffic disruption and delay costs.

It is recommended that water utilities refer to the AWWA Research Foundation document *Costs of Infrastructure Failure*, (AwwaRF, 2002).

6. EVALUATION

It is always important to gauge performance to strive for constant improvements. With respect to the speed and quality of linear system repairs, the following benchmarking initiatives can be employed.

- As performed in the electricity industry, track and report water service interruption time and the number of affected customers for each linear failure repair to obtain a yearly total interruption time that can be expressed as a percentage per customer.

- Track the water systems water balance and infrastructure leakage index (ILI). By tracking water losses, it is possible to evaluate how the increased attention to speed and quality of system repairs translates into reduced system losses.

- Track the total cost of linear system failures on an annual basis. It is important to use the total cost as outlined in the previous section.

- Track the implementation of preventive maintenance measures, such as system maintenance and watermain rehabilitation and replacement programs, to determine their effect on the occurrence of linear system failures.

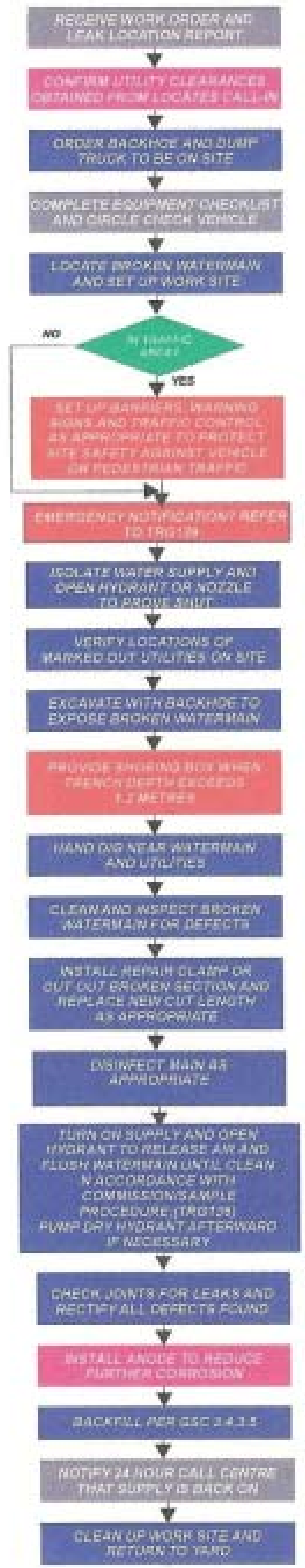
Whichever tracking and evaluation method is used, it should be carried out at least on a quarterly basis to allow assessment and documentation of improvement over previous years. This allows a utility to determine if current levels of intervention are cost effective or if they should be increased or decreased.

APPENDIX A: WATERMAIN REPAIR FLOW CHART

Please note that the following watermain repair flow chart was provided by the City of Ottawa as an example. It is part of the city's Water Distribution System Operation and Maintenance Manual. The following contact person can be reached for further details:

David Raymond
City of Ottawa – Utility Services Branch
951 Clyde Avenue
Ottawa, Ontario K1Z 5A6
Tel: (613) 580-2424 Ext. 22350
Fax: (613) 728-4183
E-mail: David.Raymond@ottawa.ca

Sample Watermain Failure Repair Activity Flow Chart



APPENDIX B: WATERMAIN REPAIR FIELD DATA COLLECTION SHEET

Please note that the following watermain repair field data collection sheet was provided by the Halifax Regional Water Commission as an example. It is part of the city's Water Distribution System Operation and Maintenance Manual. The following contact person can be reached for further details:

Ken Brothers, P.Eng.
Manager of Operations
6380 Lady Hammond Road
P.O. Box 8388 Stn. A
Halifax, Nova Scotia
B3K 5M1
Tel: (902) 490-6254
E-mail: kenb@hrwc.ns.ca

Halifax Regional Water Commission

WATERMAIN AND SERVICE LATERAL REPAIRS

BREAK TYPE: MAIN ☐ SERVICE ☐

LOCATION INFORMATION

STREET ____ OPPOSITE HOUSE NUMBER ____

INTERSECTING STREETS 1 ____ 2 ____

TIE 1 ____

TIE 2 ____

REGION: CENTRAL ☐ EAST ☐ WEST ☐ COMMUNITY ____

WATERMAIN INFORMATION

TRENCH INFORMATION: CLAY ☐ GRAVEL ☐ ROCK/SHALE ☐ TILL ☐

EXTERIOR PIPE CONDITION: FAIRLY NEW ☐ SLIGHTLY CORRODED ☐ MODERATELY CORRODED ☐ BADLY CORRODED ☐

INTERIOR SEDIMENT LIME DEPOSIT ☐

INTERIOR TUBERCULATION: HARD ☐ SOFT ☐

INTERIOR PIPE WALL: FAIRLY NEW ☐ PARTLY CORRODED ☐ CORRODED AROUND ☐ BADLY CORRODED ☐

INTERIOR WALL LINING INTACT ☐ DATE PIPE INSTALLED ____ PIPE SIZE ____

PIPE MATERIAL: ASBESTOS CEMENT ☐ BRASS ☐ CAST IRON ☐ CI CONCRETE LINED ☐ COPPER ☐ DUCTILE IRON ☐ DUCTILE IRON HYPROTEC ☐ GALVANIZED STEEL ☐ HYPRESCON C-301 ☐ HYPRESCON C-303 ☐ HYPRESCON ☐ PVC ☐ STAINLESS STEEL ☐ OTHER ____

PIPE DEPTH ____

SERVICE REPAIR INFORMATION:

PIPE ☐ SERVICE BOX OR BUFFALO BOX: SB ☐ BB ☐ STAINLESS STEEL ROD ☐ SODS ____

ADJUSTED TO GRADE: RAISED ☐ LOWERED ☐ OTHER ____

LEAK INFORMATION

DETECTION DATE ____ REPORTER ____

LEAK AWARENESS: CUSTOMER/REPORTED ☐ LEAK DETECTION UNREPORTED ☐

LEAK TYPE: CIRCULAR ☐ BLOW OUT ☐ SPLIT PIPE ☐ HOLE IN PIPE ☐ PIPE JOINT ☐ OTHER ☐

APPARENT REASON: PITTING ☐ GRAPHITIZATION ☐ BEAM ACTING ☐ SIDE MOVEMENT ☐ WATER HAMMER OR SURGING ☐ THIN WALL CAUSED BY CORROSION ☐ UNDERMINED ☐ ACCIDENTAL DAMAGES ☐ COLLAPSE BY VACUUM ☐ LOOSE JOINT ☐ OTHER ☐

WATER LOSS GALLONS ____ TOTAL REPAIR COST ____

LIABILITY INFORMATION

PRIVATE INSURANCE CLAIM ☐ **NUMBER OF AFFECTED CUSTOMERS** ____ **WATER ESCAPE** CATCH BASIN ☐ TRENCH ☐ STREET ☐ BASEMENTS ☐ YARDS ☐

TYPE OF CUSTOMER AFFECTED (CHECK ALL THAT APPLY) RESIDENTIAL ☐ COMMERCIAL ☐ INSTITUTIONAL ☐

DAMAGE TO STRUCTURES PUBLIC/PRIVATE ____

REMARKS ____

MAINTENANCE INFORMATION

WORK ORDER NUMBER ____ **REPAIR DATE** ____

TIME: CREW ON SITE ____ **WATER OFF** ____ **WATER ON** ____

FINAL GRADE SURFACE PAVED ☐ GRAVEL ☐ CONCRETE ☐ CHIPSEAL ☐ BRICK ☐

THICKNESS OF ASPHALT ____

EXCAVATION SIZE ____ **DEPTH** ____

LENGTH OF REPAIRED PIPE ____ **NUMBER OF CLAMPS** ____ **CLAMP SIZE** ____

NUMBER OF REPAIR COUPLINGS ____ **NUMBER OF ANODES** ____

HYDRANTS USED ____

VALVES USED ____

VALVES CLEANED ____

VALVES BROKEN ____

VALVES THAT LEAKED ____

EMPLOYEES AT THE BREAK ____

EQUIPMENT USED ____

OTHER MATERIAL USED ____

____

____

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