

Condition Assessment of Water Mains



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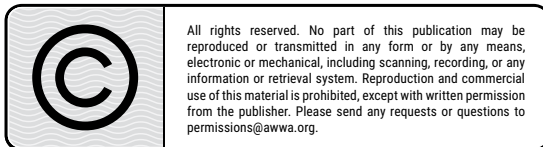
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Contents

List of Figures, vii

List of Tables, xi

Preface, xiii

Acknowledgments, xv

Chapter 1	The Benefits of Condition Assessment for Water Mains.	1
	Definition of Condition Assessment, 2	
	The Benefits and Costs of Condition Assessment, 3	
	Condition Assessment as Part of an Assess-and-Fix Strategy, 6	
	Additional Considerations When Using Condition Assessment, 7	
	References, 8	
Chapter 2	Building Support for a Condition Assessment Program.	9
	Making a Business Case for Condition Assessment, 9	
	Accounting Treatment: Ways to Account for Condition Assessment Costs, 12	
	Budgeting for a Systematic Condition Assessment Program, 13	
	Gaining Support From Policy Makers, The Public, and Other Stakeholders, 14	
	Summary, 16	
	References, 16	
Chapter 3	Planning a Condition Assessment Project or Program	19
	Levels of Condition Assessment, 19	
	Choosing an Assessment Method, 21	
	Available Technologies, 23	
	Planning of Field Work/Communications, 27	
	Contract Guidelines, 29	
	Summary, 30	
	Reference, 30	
Chapter 4	Desktop Condition Assessment.	31
	Overview, 32	
	Data Cleanup and Assessment, 32	
	Setting Level of Service Goals, 36	
	Evaluating the Likelihood of Failure Desktop Score, 37	
	Long-Term Renewal Planning, 43	
Chapter 5	External Corrosion Surveys.	47
	External Corrosion Direct Assessment, 47	
	Economic Benefits, 55	
	References, 55	

Chapter 6	Spot Assessment	57
	Strategies for Effective Spot Assessment, 58	
	Testing Procedures, 60	
	Post Assessment and Interpretation of Results, 73	
	References, 75	
Chapter 7	Leak Detection	77
	Why Leak Data Are Important for Condition Assessment, 78	
	How and When to Perform Leak Detection, 79	
	Acoustic Leak Detection, 79	
	Non-acoustic Leak Detection, 91	
	Summary, 96	
	References, 96	
Chapter 8	Internal Remote Visual Inspection	97
	Internal Visual Inspection as a Condition Assessment Tool, 98	
	Recent Advances in Remote Visual Inspection Technology, 99	
	Logistical Considerations for Performing Remote Internal Visual Inspection, 100	
	Current Methods and Technologies Available for Internal Visual Inspection, 101	
	Implementation Strategies for Internal Remote Visual Inspection, 110	
	Summary, 112	
Chapter 9	Physical Entry Inspections	115
	Overview: Physical Entry Inspections, 116	
	Summary, 124	
	References, 124	
Chapter 10	Acoustic Velocity Testing	125
	History, 126	
	Background, 127	
	Performance, 130	
	Requirements and Limitations, 132	
	References, 133	
Chapter 11	Electromagnetic Testing Technologies	135
	History and Current Use of EM Testing in Water Mains, 136	
	Technology Overview, 140	
	Defect Resolution Considerations, 146	
	Advantages and Limitations, 146	
	References, 147	
Chapter 12	Magnetic Flux Leakage	149
	Current State of the Art, 150	
	MFL Application Considerations and Inspection Logistics, 150	
	Data Output and Post Processing, 157	
	Planning and Delivering a Quality MFL Project, 160	
	Reference, 162	
Chapter 13	Condition Assessment of PCCP	163
	PCCP Construction, 163	
	PCCP Deterioration And Failure Modes, 165	
	Inspection and Assessment, 166	

	Strategies for Managing Distressed PCCP, 178	
	References, 182	
Chapter 14	Hydrostatic (Pressure) Testing of Existing Pipes	185
	The Basics, 186	
	Hydrostatic Examination, 187	
	Procedure Development, 188	
	Pressure Limits, 190	
	After the Initial Tests, 191	
	References, 191	
Chapter 15	Strategies for Economical Assessments of Low-Value Pipes	193
	Nondisruptive Sampling Methods, 194	
	Nondisruptive Screening Techniques, 195	
	Leveraging Condition Assessment Data, 196	
	The Assess-and-Fix Approach, 197	
	Forensic Analysis of Breaks, 198	
	Reference, 200	
Chapter 16	The Next Steps: Using Condition Assessment Information.	201
	Purpose of Condition Assessment Information, 201	
	Leveraging Data, 202	
	Data Analysis, 203	
	Presentation of Results, 203	
	Example Approaches, 204	
	References, 206	
Appendix A	Other Assessment Methods	207
	Acoustic Resonance Testing, 207	
	Pipe Wall Analysis Using Magnetometry, 207	
Index		209
List of AWWA Manuals		215

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Figures

- 2-1 Aerial view of Anchorage, Alaska, railroad yard, 11
- 2-2 Progressive condition assessment and resulting actions, 14
- 3-1 The tradeoffs between costs, coverage, and degree of inspection, 20
- 4-1 Decision tree process for GIS CoF scoring, 40
- 4-2 Risk matrix, 41
- 4-3 Example of color-coded risk mapping, 42
- 4-4 Example decay curve based on two known points, 43
- 4-5 Example of optimizing pipe EUL by considering CoF scores, 44
- 4-6 Example of using GIS to predict funding needs based on service levels, 45
- 5-1 Graphical representation of soil resistivity fluctuations along a pipeline alignment as measured using Emag and comparison to Wenner 4-pin results, 50
- 5-2 Graphical representation of cell-to-cell, close-interval survey results along pipeline alignment, 52
- 5-3 Depth of cover, soil resistivity, and close interval potential survey indirect inspection data aligned along pipeline rights-of-way, 54
- 6-1 Measuring the depth of corrosion pits in cast-iron pipe, 62
- 6-2 In situ pH testing of concrete pipe using phenolphthalein, 62
- 6-3 Ultrasonic thickness measurement, 64
- 6-4 Potential mapping, 65
- 6-5 In situ electrochemical testing, 66
- 6-6 Sampling slime for MIC testing, 67
- 6-7 Identifying corrosion products using SEM/EDS, 69
- 6-8 Optical microscopic pitted surface (top); pit depth profiling (bottom), 70
- 6-9 Comparative metallographic analysis of heat-treated (welded) zones, 71
- 6-10 Petrographic analysis of concrete, illustrating cracks, 71
- 6-11 [ASTM B117](#) test on heat-treated areas of stainless steel (1000 h of testing in salt chamber), 72
- 6-12 Phenolphthalein stain testing of asbestos cement pipe, 73
- 7-1 Leak detection techniques covered in this chapter, 80
- 7-2 A leak detection monitor installed in a below-ground chamber, 84
- 7-3 A leak detection sensor connected to a service line at the meter , 85
- 7-4 A leak detection node contained in a hydrant cap, 85
- 7-5 A typical communications network, 85
- 7-6 Typical node layout on a transmission main (top) and a node installation in an above-ground pedestal (bottom), 87

- 7-7 Tethered leak detection tool, 89
- 7-8 Free-swimming leak detection device, 90
- 7-9 Gas tracer leak detection method, 91
- 7-10 Basic diagram of low-voltage conductivity circuitry, 94
- 7-11 Steps in data capture, analysis, and display with satellite-based leak detection, 95

- 8-1 Images from a CCTV inspection of a 21-in. steel water main, with close-up of an exposed joint (right), 98
- 8-2 Example of a side scan camera deliverable, 99
- 8-3 Digital video and hydrophone sensor head (left); field deployment of tethered sensor head into live transmission main (right), 100
- 8-4 Laser scan with better than 2-mm accuracy exported to AutoCAD for manipulation and analysis for areas of concern (i.e., 1, 2, and 3), 103
- 8-5 Examples of crawling ROVs with CCTV cameras, 103
- 8-6 Image from a high-definition camera with zoom capability on crawling ROV, 104
- 8-7 Image from a high-definition camera on crawling ROV in dry conditions, 104
- 8-8 Tethered CCTV insertion setup (top left), tethered CCTV setup through a fire hydrant (top right), and operation of a long-range system with parachute to propel the sensor with flow (bottom), 106
- 8-9 Real-time, forward-looking sonar data showing a grate in a flooded pipe, 107
- 8-10 Typical cross-sectional view of profiling sonar data, 107
- 8-11 Flooded tunnel visualization using multiple multibeam sonars, 108
- 8-12 Advantages of combining profiling and forward-looking sonar sensors, 109
- 8-13 Sample output from an underwater laser scan of a horseshoe-shaped conduit, 110
- 8-14 A laser scan of a dewatered conduit using a stationary laser platform, 110

- 9-1 Demonstration of physical entry in various pipe diameters, 117
- 9-2 Electronic data collection during physical entry inspection, 122

- 10-1 AV testing history and progression timeline, 126
- 10-2 Validation database, 127
- 10-3 Typical setup for an acoustic velocity measurement, 128
- 10-4 In-pipe acoustic velocity system, 130

- 11-1 Example of a free-swimming tool, 137
- 11-2 Example of a high-resolution, large-diameter tool, 137
- 11-3 Example of a self-propelled crawler, 138
- 11-4 Example of a handheld tool, 138
- 11-5 Example of a manually winched tool, 139
- 11-6 Example of a hydrant-launched, water-propelled tool, 139
- 11-7 Simple probe for remote field testing, 140

- 12-1 MFL field in unlined pipe, 151
- 12-2 MFL field in lined pipe, 152
- 12-3 B-H curve, 152
- 12-4 Typical MFL ILI tool in CML pipeline, 154

- 12-5 Test data in ½-in. pipe with ½-in. mortar lining, 155
- 12-6 Isolated pipeline defects, 156
- 12-7 MFL data from severely corroded pipeline and removed pipe showing corroded area, 156
- 12-8 MFL view of circumferential corrosion and exposed pipe showing circumferential corrosion, 157
- 12-9 Color contour C-scan of blind test defects, 158
- 12-10 Graphical depiction of pipeline defect anomaly definitions, 159

- 13-1 Pre-stressed concrete cylinder pipe, 164
- 13-2 Break rates for PCCP manufactured in different eras, 167
- 13-3 Typical tools and equipment used in visual and sounding inspections, 168
- 13-4 Example of longitudinal crack surrounded by hollow, 169
- 13-5 Electrical currents induced by time-varying magnetic field, 171
- 13-6 Technician pushing an electromagnetic inspection cart through a PCCP, 172
- 13-7 Tethered and untethered robotics platforms equipped with electromagnetic inspection technology, 172
- 13-8 Example of pipe excavation for external electromagnetic inspection, 174
- 13-9 Illustration of sonic/ultrasonic testing of PCCP, 176
- 13-10 Fiber optic cable anchored to pipe in dry deployment (left) and deployed into in-service pipeline in wet deployment (right), 178

- 14-1 Catastrophic break due to bad weld at intersection between 30-in. and 36-in. pipes, 187
- 14-2 Pressure testing for LADWP, 189

- 15-1 Electromagnetic scanning of pipe within keyhole excavation, 198
- 15-2 Keyhole excavation with pavement repair, 195
- 15-3 Acoustic velocity testing on a Los Angeles trunk line, 196
- 15-4 Inserting an RFT tool into the hydrant lateral of a shallow-buried main, 197
- 15-5 Photo showing insertion of the RFT tool during assess-and-fix demonstration in Phoenix, 199
- 15-6 Fracture analysis of a PVC pipe break, 199

- 16-1 Condition assessment data displayed in Google Earth, 204
- 16-2 Summary table, 205

- A-1 Pipe wall analysis using magnetometry, 208

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Tables

- 1-1 Typical condition assessment project items, 5
- 1-2 Simple cost-benefit analysis for condition assessment of a 10-mile, large-diameter pipeline over 10 years, 6
- 1-3 Simple cost-benefit analysis for condition assessment of a cast iron pipeline over 10 years, 6
- 3-1 Available inspection technologies for pressure pipe, 24
- 4-1 2018 AWWA Benchmarking Survey Distribution System Integrity results (combined leaks and breaks/100 mi/y), 36
- 4-2 Example criteria and weightings for LoF scoring, 38
- 4-3 Example criteria and weightings for CoF scoring, 39
- 4-4 Example criteria for GIS-based CoF scoring, 40
- 6-1 Common in situ field and laboratory tests for spot assessment, 60
- 7-1 Parameters for sounding equipment, 81
- 7-2 Parameters for listeners, 81
- 7-3 Comparison of leak detection correlators, 82
- 7-4 Parameters for correlators, 82
- 7-5 Parameters for leak loggers, 83
- 7-6 Parameters for remote correlating leak detection systems: distribution systems, 86
- 7-7 Parameters for remote leak detection systems: transmission mains, 87
- 7-8 Parameters for tethered devices, 89
- 7-9 Parameters for free-swimming devices, 91
- 7-10 Parameters for gas tracer method, 92
- 7-11 Parameters for ground-penetrating radar, 93
- 7-12 Parameters for thermography, 93
- 7-13 Parameters for low-voltage conductivity testing, 95
- 7-14 Parameters for satellite-based leak detection, 96
- 8-1 Inspection platform/method options, 102
- 8-2 Operating parameters for tethered CCTV inspection, 105
- 8-3 Relative costs of internal inspection methods and technologies, 112
- 9-1 Complementary testing techniques performed during physical entry inspection, 123

- 11-1 Available tools using electromagnetic technology, 141
- 12-1 Definitions of pipeline anomalies, 158
- 12-2 Estimated performance specifications, 160
- 14-1 Dispersion scenario and appropriate testing method, 188
- 14-2 Test pressure limits, 190

Preface



Water main condition assessment currently ranks among the most important subjects to water utilities, and interest in this subject is rapidly growing. As the average age of their infrastructures increases, utilities are increasingly challenged to maintain levels of service while keeping water affordable to all. Condition assessment helps utilities meet this challenge by identifying more precisely where money is best spent, leaving in place pipelines that have adequate integrity and preventing the unnecessary failures of others.

The assessment of buried pipelines is never simple, and water mains are particularly challenging. They are difficult to access, and concerns exist regarding water contamination and the need to maintain water service for sanitation, commerce, and fire protection. Because water main condition assessment is relatively new, there's a scarcity of authoritative, peer-reviewed material to guide utilities. Instead, utilities often are left to rely on the claims of inspection companies, some of which are not well established. This manual fills an important need, providing a comprehensive overview of the many methods that can be used to assess water mains.

Methods range from desktop studies to leak detection to full-length, high-resolution scans from inside the pipes. The choice of method and the interpretation of results are both art and science, with decisions based on economics and risk tolerance. This manual provides the technical information utility managers and engineers need to make informed decisions, along with practical information about how methods can be deployed.

For assessment of most pressure pipelines, a multistep approach is recommended. By starting with simpler, less-expensive examinations, then progressing if necessary to more expensive techniques, resources can be leveraged. Assessment is meant to answer questions about questionable pipes, where a decision is needed that affects service or cost. Assessment is usually less useful when applied to pipes that are known to be in very good or very poor condition. Pipes may be distribution or transmission mains, where the consequences of a break range from mundane to intolerable. In either case, with condition assessment, decisions can be made more confidently and the likelihood of a poor decision reduced. Risks are better managed.

This manual is largely organized around the various inspection methods, with chapters also devoted to program management. The physical inspection techniques focus on detecting degraded materials—corroded metal in particular. Readers should keep in mind that other causes of main failure, including ground movement (pipe bending), pressure surges, casting defects, poorly made welds, and other joint problems may be difficult (if not impossible) to detect in advance of failure.

It is important to understand the limitations of the various inspection methods: what sizes and types of defects might be missed; whether the method has been verified by independent, third-party verifications (dig-ups); and where blind spots exist. Several methods, for instance, have difficulty finding defects near pipe joints. Irregularities such as riveted seams or heavy scales may produce “noisy” data. No method is perfect, and no inspection method finds all possible defects. The methods and techniques included in this manual have been reviewed by the Water Main Condition Assessment Committee and found to be worthy of consideration, but not all have been proven through years of use and *independent* testing. Inclusion in this manual does not imply AWWA or committee endorsement of any particular method or the companies that provide it. Utilities are encouraged to start with the information presented in this manual, consult other publications, seek referrals, and ask hard questions before investing.

The applicability of these methods varies depending on pipe material. Some methods apply to all types of pipe, while others apply more narrowly to metal or reinforced concrete pipes. The focus is also on water mains (large and small). It is usually not economical to assess small service laterals with these methods. Chapter 3 provides guidance regarding which methods can be used for which types of pipe and also regarding selecting and procuring services. This manual focuses on methods that are commercially available in North America, and because the field is rapidly evolving, other methods are expected to be introduced in the next few years. A few of these are listed in Appendix A.

Unlike the other chapters in this manual, Chapter 13 addresses one specific material: prestressed concrete cylinder pipe (PCCP). PCCP has been particularly problematic due to its propensity to fail without warning and in a catastrophic manner. As a result, much attention has been paid to the assessment of PCCP, and many tools and techniques specific to this type of pipe have been developed. Some of these tools are now being applied to other types of material, particularly bar-wrapped steel cylinder concrete pipe.

Through the publication of this manual, AWWA hopes to provide practical information that water utilities will use to better manage their systems. AWWA also seeks your feedback regarding this manual and other ways to advance this important discipline. This marks the start of a continuous, dedicated effort to collect and disseminate reliable information on water main condition assessment. Your participation in this process is welcomed and encouraged.

—Water Main Condition Assessment Committee
Dan Ellison, PE – Chair

Acknowledgments



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Dedication: This manual is dedicated to Phil Hoyt, who pioneered the use of magnetic flux leakage for water pipeline inspections. Phil contributed greatly to this manual and, sadly, passed away before seeing its completion.

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Chapter **1**

The Benefits of Condition Assessment for Water Mains

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This chapter describes generally what condition assessment is and what it can accomplish. In brief, condition assessment involves the deployment of methods to ascertain the physical condition of a water main. By performing condition assessment of water mains, a utility can

- estimate the likelihood that a water main may continue to provide satisfactory service, both now and in the future;
 - help determine the remaining service life of the water main;
- make better decisions regarding main renewals;
 - allow some water mains to remain in service longer;
 - prevent some pipeline failures from occurring by intervening sooner;
 - make decisions more confidently (with less chance of error);
- find active leaks; and
- tailor renewal projects and methods to better match the conditions of the mains.

DEFINITION OF CONDITION ASSESSMENT

The emphasis of this manual is on methods of pipeline condition assessment to identify physical condition. Condition assessment may be defined as the identification of the likelihood that an asset will continue to perform its required function. As part of condition assessment, data and information are collected through direct and/or indirect methods and then analyzed to determine the physical characteristics of the pipe and how they may impact the pipeline's likelihood that it will leak, break, or otherwise fail to perform. Example characteristics include current or future structural, water quality, and hydraulic status of an individual pipe, segment, or collection of similar pipes, among other characteristics.

Condition assessment may be performed in the field, via desktop, or both. The important objective is to do it, update it, and improve upon it as needed. Field condition assessment involves direct and indirect observations of the asset and its environment to determine and document its condition. Desktop condition assessment relies more heavily on existing data and institutional knowledge to make the same determination using design documents, staff knowledge, information systems, industry experience, and other resources to determine or approximate the condition of the pipelines without viewing them physically. Beyond these efforts, condition assessments may use more advanced study and testing to more fully identify pipeline condition.

Some examples of how a condition assessment is used include

- to identify loss of integrity, and that water is leaking—water loss may be observed or detected indirectly through acoustic methods;
- to identify loss of structural competence or weakening of the pipe or that the wall thickness is diminished—wall loss may be established through a variety of methods;
- to find evidence of liner or coating failure—may be visually observed; and
- to recognize other conditions of concern, e.g., pipe is unacceptably out of round.

Condition Assessment and Monitoring as Part of a Risk-based Asset-Management Strategy for Pipes

A fundamental activity for any water utility is to determine the risks associated with asset failure. Understanding the risk of asset failure and determining an acceptable level of risk for the utility allows the balancing of conflicting goals of minimizing lifecycle costs of assets versus delivering the stipulated levels of service (LoS). Risk analysis is used to understand the cause, effect (consequence), and likelihood of events adverse to attainment of LoS; managing such risks to an acceptable level; and providing an audit trail for the management of risks.

Mathematically, risk from a failure can be expressed as the product of the consequence of the failure (CoF) and the likelihood of the failure (LoF):

$$\text{Risk} = \text{CoF} \times \text{LoF}$$

Risk analysis is used to rank assets by their risk of failure and to identify high-risk assets (i.e., assets with a risk of failure above an acceptable level of risk). In assessing risk, CoF and LoF are quantified separately, and the results can be multiplied to calculate the risk-of-failure score of a specific asset.

An asset is considered to be failing if it cannot, or does not, provide the requisite LoS. For water mains, this failure is measured by physical condition, hydraulic performance, and quality of water. Thus, when determining the LoF of a pipeline, these three factors should be assessed, with the physical condition being the most prominent one.

The risk associated with each water main can be quantified by multiplying the CoF and LoF values to arrive at a relative risk score. Often a scale such as 1 to 5 is applied to both CoF and LoF. Applying the risk equation to each of the water mains under consideration allows for a comparison of the mains by their relative risks. Because the scoring is somewhat subjective, the absolute risk score value itself is not as important as is the relative risk ranking of a main. Listing the mains by their relative risk score usually makes clear which mains are posing the highest risk, which are posing the next highest risk, and so on. The relative risk score is then used to help identify options for risk mitigation.

When computing LoF scores, water utilities typically have limited condition information on all the water mains in their system. This information might consist of break and leakage data for some of the mains, field condition analysis data on a few critical mains, etc. Furthermore, some asset data used might be dated, incomplete, or unreconciled, and therefore less reliable. For the remainder of the mains, most of the information that is used is typically based on institutional knowledge and the application of cohort analysis techniques. Thus, when the risk score is calculated for all the water mains in a system, these scores need to be vetted, especially for the high-risk mains for which mitigation measures such as rehabilitation or replacement might be considered. Before making any significant investments for mitigation, it is important to verify the validity of the data used by conducting further condition assessment activities on these mains.

Condition assessment is a fundamental element of the strategic asset-management effort. It helps capture and make available timely information including pipeline condition and pipeline attributes (e.g., identifiers, sizes, materials, and uses) that are used to implement an asset management program. Condition assessments can be recurring and may be improved upon in future iterations. Initial condition assessment will provide key elements of asset management to establish minimum initial awareness of asset condition and needs, as well as a baseline of these for future comparisons. Condition assessments are also useful to

- show and realize progress in and benefits of asset management;
- engage staff members and attract their participation, contributions, and buy-in; and
- increase value in the short-term and long-term pipe-renewal investments for the asset-management effort.

The accomplishments of condition assessment contribute to the organizational aspects of service levels, strategy, risk, prioritization, process efficiency and effectiveness, quality information systems and tools, performance monitoring, and others.

THE BENEFITS AND COSTS OF CONDITION ASSESSMENT

Benefits of Condition Assessment

The overarching benefit of condition assessment is the ability to gather data for risk-based decision making. Condition assessment data can therefore lead to better and more defensible decisions and the reduction of risks associated with water mains. Most agencies strive to achieve efficient operations through main break avoidance and efficient renewal planning.

Condition assessment data can lead to break avoidance by identifying and proactively repairing pipes that are likely to fail. Avoiding breaks can also lead to customer benefits including more reliable service, reduction of unplanned outages, and positive customer perceptions. The financial benefits of break avoidance include lower repair costs for planned repairs, less damage to surrounding infrastructure, and more defensible

claims from private parties stemming from pipe failures (Martel 2014). Social impacts of pipe breaks include traffic and business disruptions. Also, there are environmental benefits to avoiding breaks, such as habitat damage, unnatural sediment buildup, and negative water quality impacts from discharged water.

Another key benefit of condition assessment data is efficient renewal planning. Condition assessment provides data to support and justify better planned pipe-restoration projects. Utilities can focus renewal efforts on pipelines that need repair rather than basing decisions on general characteristics that may not correlate to actual condition such as age. In many cases, condition assessment efforts reveal that most of the pipeline is in good condition. This information helps utilities avoid unnecessary pipe replacements. If only a small part of the pipeline needs repair, utilities can focus their repair efforts on these areas and benefit from extended use of the sections of the pipeline that are in good condition. Understanding the repair needs for the long term (10–20 years) helps the utility plan and execute those projects and schedule projects in a sustainable way with regard to resources. Condition assessment data can also help define project boundaries and bundle similar projects to reduce community impacts and lower project mobilization costs. The condition assessment data also support the utility's decision for a renewal project to both internal and external stakeholders. In many cases, the utility can physically show the data to stakeholders to effect understanding and context of the repair need. Finally, condition assessment data can confirm or even extend the assumed life of a pipeline. For example, a condition assessment effort might indicate that an old pipeline previously thought to need replacement is in good condition and can continue to provide service for decades longer.

Costs of Condition Assessment

The costs of condition assessment vary greatly depending on the type of condition assessment, location, size, requirements, access, environment, assessment methods, and system complexities. This section is meant to serve as a guide to the various costs that may apply. The utility owner should determine whether a given cost applies and develop an estimate. Table 1-1 provides a list of important items that the utility should consider including in a condition assessment project.

Cost-benefit examples. To illustrate the justification for condition assessment, two simple cost-benefit comparisons were developed: one for a large-diameter case and one for a small-diameter case. We are using two techniques, magnetic flux leakage (MFL) and remote field technology (RFT), for illustrative purposes only. The case for using other techniques can also be made. The point is that the cost of condition assessment (for these two techniques and for others) can be justified. The first analysis looked at a future MFL condition assessment project. The comparison is for a 10-mile, steel, large-diameter (84-in.) pipeline over a 10-year term. The costs were based on past project costs and included preparing, draining, accessing, and filling the pipelines. The assumption was made that as a result of this condition assessment, four locations of significant corrosion would be identified and repaired. For prevention of a pipeline leak, the low repair costs were based on fixing four leaks over 10 years, each at a cost of \$300k, which includes a pipeline shutdown, draining, access, repair, filling, and property damage/claims due to leaks. The high estimate of \$6 million is due to an estimated \$1.2M for each leak in additional property damage and claims impacting several homes, structures, businesses, and other utilities. Proactive repairs based on an MFL condition assessment would have a benefit of avoided repair and damage costs ranging from \$1.2M to \$6M over a 10-year period. The life extension benefits are based on the estimated cost of constructing a replacement pipeline, which would last 100 years, with new construction costs of \$88M in a rural area and \$120M in an urban area.

Table 1-1 Typical condition assessment project items

Vendor/Contractor Costs	
1	Mobilization
2	Work execution
3	Analysis
4	Reporting
Owner Costs	
1	Planning/coordination (meetings, schedules, correspondence, plans, calculations, permits, forms, and notices)
1-1	Customers (service interruptions, temporary service, water storage)
1-2	Public (notification, accommodations)
1-3	Regulatory agencies (water discharge, disinfection, work permits, traffic permits)
1-4	Contractors (scheduling and coordination)
1-5	Other needed pipeline maintenance, repairs, and/or upgrades
2	Preparation
2-1	Safety (pipeline isolation, communication, emergency protocols, lockout/tagout, ventilation, trench shoring, equipment)
2-2	Access to facilities/pipeline (vehicles and equipment) and access inside pipeline (valve removal, excavations, flange removal)
2-3	Water discharge/erosion control
2-4	Equipment availability/functionality (e.g., generators, pumps, air blowers, trench shoring, trench plates, discharge filtering, portable restrooms, cranes, small tools)
2-5	Valve testing/functionality/configuration
2-6	Contracts/agreements for water service and/or water supply
2-7	Material needs (gaskets, nuts, bolts, paint, grease, coatings, couplings, paving, sand, gravel)
3	Implementation
3-1	Pipeline access, draining, excavation, ventilation
3-2	Visual inspections
3-3	Planned and unplanned pipeline maintenance, repairs, and/or upgrades
3-4	Contractor/vendor condition assessment work execution
4	Protocols
4-1	Communication and progress reports
4-2	Safety (equipment, rescue teams, lockout)
4-3	Traffic control
4-4	Pipeline disinfection and testing
4-5	Equipment and materials (see above)
5	Data integration
5-1	Review
5-2	Field verification
5-3	Analysis
5-4	Integration with existing data

To calculate the avoided costs based on a life extension for 10 years, these replacement costs were depreciated (straight-line) over a term of 10 years. Table 1-2 illustrates the simple cost-benefit comparison.

The second analysis looked at a 12-in. (30.48-cm) diameter cast iron pipeline condition assessment project using RFT. The comparison is for a 4,000-ft (1,119-m) section of pipeline over a 10-year term. The simple cost-benefit comparison is provided in Table 1-3.

Table 1-2 Simple cost-benefit analysis for condition assessment of a 10-mile, large-diameter pipeline over 10 years

	Description	Assumptions	Low Cost*	High Cost†
Costs	MFL condition assessment	Total project	\$1.5M	\$2.0M
	Steel repairs	Internal steel patches (4 total)	\$30k	\$30k
Benefits	Prevention of a pipeline leak	Damage and repair costs (4 leaks total)	\$1.2M	\$6.0M
	Avoided depreciation cost	10-year life extension	\$8.8M	\$12.0M
Net cost savings:			\$8.5M	\$16.0M
Benefit/cost ratio:			6.7	9.0

MFL—magnetic flux leakage

* Rural area

† Urban area

Table 1-3 Simple cost-benefit analysis for condition assessment of a cast iron pipeline over 10 years

	Description	Assumptions	Low Cost	High Cost
Costs	RFT condition assessment	Total project	\$100k (access available)	\$300k (excavation and pipe modification for access)
	Repairs	3 repairs	\$120k	\$150k
Benefits	Prevention of a pipeline leak	Damage and repair costs (3 leaks total)	\$120 (low consequence)	\$840k (high consequence)
	Avoided depreciation cost	10-year life extension	\$400k	\$400k
Net cost savings:			\$300k	\$790k
Benefit/cost ratio:			2.4	2.8

RFT—remote field technology

CONDITION ASSESSMENT AS PART OF AN ASSESS-AND-FIX STRATEGY

The objective of assessing the pipe is to understand the condition of the pipe. Some interest exists in the industry to use condition assessment as part of a structured water main rehabilitation program. The concept is that using condition assessment tools to measure wall loss can aid in the maintenance of small-diameter, less consequential aging iron pipes, especially those that have never been lined. Water Research Foundation Project 4473 described and demonstrated this approach: using nondestructive examinations (remote field technology was the applied technology in the demonstrations) to help the utility select a lining system based on the assessed pipe condition (Bell 2015). Lining systems vary from nonstructural methods applicable to mains with little corrosion to semistructural to fully structural liners to carry the pipe loads where significant corrosion and wall loss has occurred.

This strategy is commonly applied to nonpressurized sewer pipes, where rehabilitation methods are selected based on video assessment results. Several factors make this more challenging for pressured water pipes: the high cost of assessments, the difficulty of putting assessment tools into the pipe, taking mains out of service and associated customer impacts, the concern about water quality when tools are introduced into the pipe,

the difficulty of interpreting the assessment data, and the lack of utility experience with the approach or the availability of guidance. Nevertheless, it is both feasible and often cost-effective. This will be described in more detail in Chapter 14 of this manual.

ADDITIONAL CONSIDERATIONS WHEN USING CONDITION ASSESSMENT

Concerns and Challenges of Condition Assessment

Condition assessment challenges include providing reliable data that have a sufficient level of detail and locational accuracy to make informed decisions. In many cases, the utility's expectations do not align with what the contractor hired to conduct a condition assessment is planning on providing. A number of factors, including calibration of the equipment, the accuracy of the data being provided, and the assumptions based on pipe characteristics, can impact the reliability of the data.

Funding and/or technical issues may limit a utility's condition assessment options. Operational complications due to shutting pipelines down, achieving proper isolation, and recharging and disinfecting the line can be a challenge. In some cases, the utility may not have the required system information such as pipe plans, manufacturing details, locations, and/or repair information. At the end of a project, the utility may not understand the significance of the findings and know how to act on the data. In many cases, the data may not be compatible with existing data formats, and it may be difficult to integrate them. On some projects, the utility may not be fully aware of the limitations of the data, and these are not disclosed before the project.

The contractor sometimes assumes important details about a utility's system, or the utility does not properly convey system information such as pipe interconnections, isolation valves, previous repairs, and/or operational parameters. For example, there should be a clear understanding of when and where the contractor would be allowed to operate water system valves. Additionally, the data interpretation may be difficult for the contractor to convey and difficult for the utility to understand.

Predictive Failure Analysis

The knowledge and data derived from condition assessment may be used in predictive analytics to forecast probable time ranges of likely pipeline failure. Also, trending of the existing pipelines and trends of historical similar pipelines may be used in this effort. A variety of modeling and statistics may be leveraged to develop predictions of pipeline failure. By applying the knowledge of current condition captured in the assessment, these endeavors help to construct a typically more realistic curve of pipeline failure rather than assuming a linear degradation over time based only on such attributes as type, material, age, type of use, etc. They also help to customize the curves more to the particular organization and its pipelines because they leverage actual information rather than relying solely on industry generalizations.

These analytics may be advanced to enable scenario analyses based on operation, maintenance, performance, and other drivers to forecast pipeline failure risk, timing, and modes, often in almost real-time dashboard environments. Geospatial and hydraulic modeling software may be helpful to access, manage, and communicate the information of the predictive or real-time analyses. Modeling can also be used to quantify the CoF, helping the utility to prioritize which pipes should have priority for condition assessment.

Predictive analytics is especially useful in situations where current condition is unknown, inaccessible, and/or cost prohibitive to capture and is especially useful for pipe networks. Various studies are exploring predictive analytics, and standards such as

International Standards Organization (ISO) 24516, “Guidelines for Management of Assets of Water Supply and Wastewater Systems,” are giving recognition to the field.

The costs associated with predictive analytics include the capture, management, and manipulation of various pipeline data and asset condition information and could also include a myriad of other information depending on the intended scope of the predictive effort. Costs also include the staff time involved in the predictive modeling and could increase with the use of geospatial and hydraulic modeling software, though such software may already be on-hand.

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Chapter **2**

Building Support for a Condition Assessment Program

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An effective condition assessment program requires funding, which requires support from the public, managers, and other stakeholders. This chapter discusses ways to build support by

- making a business case for condition assessment;
- developing effective methods for accounting for condition assessment costs;
- developing an appropriate budget; and
- gaining support from policy makers, the public, and other stakeholders through effective communications.

MAKING A BUSINESS CASE FOR CONDITION ASSESSMENT

Business case evaluations are key components of advanced asset-management programs at many water utilities. Condition assessment business cases, in particular, are important for water systems where the value of the infrastructure is under-appreciated. Like any capital investments, business cases can be developed to justify the expenditure

of funds to perform condition assessment. Given the wide array of degradation rates for buried water pipelines, best practices demand that business cases be prepared (Committee Report 2016).

The purpose of condition assessment may be to validate, estimate, justify, or improve the quality of decisions regarding water assets (Vanrenterghem-Raven and Vause 2015). Whereas desktop or statistical means may be used to assess condition and performance levels of specific assets, physical condition assessment can augment such measures. For example, when using desktop analysis of existing utility data to statistically determine the degradation of pipe cohorts, insufficient data may be a limiting factor; in such cases, condition assessment is used to validate other methods used to describe asset performance. If knowledge regarding a specific pipe segment is desired, or if utility-specific data are lacking and statistical methods are therefore impractical, condition assessment can be employed to evaluate the performance of asset groups that behave in a similar manner.

Condition assessment is also used to validate other methods used to describe asset performance. Where proper application of desktop analysis suggests it is cost-effective to invest in rehabilitation or replacement of investments, field condition assessment can be used to justify the right amount of expenditures and to determine specific assets to renew. Finally, condition assessment results can improve upon desktop or statistical analysis of asset performance, wherein the cost of condition assessment is justified by the degree of risk mitigation achieved, and lead to improved targeting of capital (e.g., identifying pipe needing repairs, renewal, or replacement). For example, a major break on a large pipe may not justify replacement of miles of pipe if condition assessment reveals that only a few sections merit attention.

Business Cases for Condition Assessment

Business cases for condition assessment are typically predicated upon demonstration that the expense associated with the effort offsets otherwise planned investments, reduces risk costs, or validates asset integrity to develop reliable estimates of asset deterioration over time. Several utilities have documented returns on investment of 400–800 percent when implementing an “assess-and-address” approach, in which condition assessment is used to find and target specific pipe defects rather than replacing an entire main. Additionally, several utilities have been able to use capital, as opposed to operational, budgets (Coghill et al. 2014) for pipeline condition assessment and repair since the projects are extending the useful life of assets that may have previously had zero book value based on their age.

One example that illustrates the value of using a business-case approach to condition assessment includes the experience of Anchorage Water Wastewater Utility (Vanrenterghem-Raven and Vause 2014). The utility used statistical methods to conduct in-depth failure analysis of its pipe inventory by accessing power analytical tools. With its own internal capabilities, the utility developed correlations between pipe types and break rates and created its own plan for replacement of sections of its distribution system. One section of the system contained high-consequence, small-diameter metallic pipe situated in a railroad yard terminal (Figure 2-1).

One section of the distribution system surrounding the rail yard was recommended for replacement using the utility’s economic replacement model, which used a triple-bottom-line failure costing technique in conjunction with statistical failure modeling. Several failures of that section were the primary drivers for replacement. Nearby sections of the distribution system were also recommended for replacement following engineering review, despite limited break history, based on proximity and similarity (same vintage, material, and installation) to the pipe section originally recommended for replacement. To justify these expenditures, additional detailed condition assessment was recommended to confirm the replacement need.



Source: Vanrenterghem and Vause 2014

Note: Blue lines are water mains, and red lines are service laterals.

Figure 2-1 Aerial view of Anchorage, Alaska, railroad yard

Given the high consequence of pipeline failure (CoF) within the rail yard, which included direct costs of interrupting the Alaska Railroad's commercial activities (involving freight shipments and passenger tourism), plus the cost of emergency repairs, product loss, potential fines, and flooding impacts, a high-resolution condition assessment technology was selected. Deployment required close coordination between the utility, its contractor, the Alaska Railroad, and water customers in the vicinity of the rail yard. Scheduling of the work was complicated by the need for the railroad to maintain train operations in the project area. The costs were considerable, because inspected pipe included unlined cast-iron sections with moderate tuberculation, and excavations were needed for insertion of the inspection equipment. Burial depths exceeded 10 ft, consistent with Anchorage's practice of placing mains very deep for freeze protection.

Results showed remaining pipe wall averaged between 86 and 96 percent of original pipe wall thickness in inspected sections, with few localized defects requiring repairs. Pipe integrity over the full length of inspected sections revealed no leaking sections. As a result of this high-resolution inspection, the utility made the decision to forego much of the planned replacement and to focus on lower-cost repairs to limited sections of the pipe. The savings were substantial.

The costs of assessment included contract inspection and analysis, laboratory pipe coupon testing, and pipeline access construction, plus internal costs for engineering, project management, and distribution system operations support. Expenses totaled more than \$500,000.

Benefits included a reduction of capital project scope as compared to the original engineering analysis and replacement recommendations, which totaled \$2.11 million. It also included avoiding a future annual depreciation expense of newly installed pipe, estimated at nearly \$39,000. In terms of value of all benefits, total annual savings to the utility were calculated to be \$166,000 per year, creating a payback period of 3.4 years for the condition assessment expense.

Moreover, the utility calculated the net present value of 20 years of risk reduction achieved by performing condition assessment and an altered project scope. Risk reduction was achieved by avoiding potential expenses of interrupting an important economic activity (commercial activities of the Alaska Railroad). The triple-bottom-line risk cost was estimated at \$3.7 million. This expense reflected the costs of emergency repairs, social impact (railroad impact), and associated environmental impacts from mainline breaks. Net risk reduction savings were determined to be \$1.5M after counting for condition assessment and the revised project scope, demonstrating value gained by this approach. Comfortable

with these results, the utility now uses similar practices for its program of pipeline replacement and has received support from its governing board in subsequent requests for program funding.

ACCOUNTING TREATMENT: WAYS TO ACCOUNT FOR CONDITION ASSESSMENT COSTS

Utilities interested in using condition assessment are often faced with challenges in getting staff agreement over proper means to account for the expenses to be incurred. If condition assessment work can be capitalized, it is often easier to fund because capital improvement funding is considered an investment rather than a mere cost. The argument for capitalization is that condition assessment can create value—adding new life expectancy to mains that have been fully depreciated. Unfortunately, this argument is often a hard sell.

The treatment of expenses associated with condition assessment requires adherence to generally accepted accounting principles. As a rule of thumb, for municipally owned utilities, all preliminary costs leading to the activation of a pipeline condition assessment project, including desktop analysis of breaks and leaks, landslide and soil movements, ground deformation, over-the-line survey on impressed current potential measurements, soil resistivity, other pipe corrosion factors, and other studies identifying sections of pipe with high consequence or high likelihood of failure, should be expensed, not capitalized. Routine pipeline inspection is typically expensed.

Certain private water companies may have access to state programs that allow for rate increases for non-revenue producing investments to replace aging infrastructure. Therein, latitude may exist for condition assessment to be capitalized. As one example, the Distribution System Investment Charge (DSIC) program was started in Pennsylvania in 1996. Benefits include more efficient and timely investment of capital, significant progress in replacing aging infrastructure, enhanced service quality, reduction of water leaks, rate shock avoidance, and others. Asset rehabilitation or replacement are capitalized items under the DSIC program.

Capitalization of condition assessment is often acceptable if the following conditions are met:

- the likelihood of replacement or improvement of the assessed section of pipeline becomes *reasonably certain*;
- the future improvement or replacement qualifies for capitalization; and
- the estimated total pipeline condition assessment project cost exceeds a utility-designated threshold—say, \$100,000.

Reasonably certain is defined as follows.

- Preliminary findings support that a qualified capital improvement will need to occur. Preliminary findings support includes a desktop analysis identifying sections of pipe that have a high consequence or high likelihood of failure based on leak repair history, site-specific inspection records, ground deformation, soil resistivity, and other pipe corrosion/degradation factors, as well as condition assessment results.
- The capital project for replacement/improvement is included in the capital improvement plan, and funding is available.
- The activation of the conduit condition assessment project has been approved by management for creation, and it is expected that more than 50 percent of the assessed pipeline will be replaced or improved through some level of rehabilitation.

Pipeline condition assessments will be capitalized as an ancillary cost of the future pipeline improvement or replacement.

Qualifications for capitalization of the replacement or improvement will typically include meeting both of the following criteria:

- total improvement or replacement meets the utility's capitalization threshold for infrastructure, which is typically set at an amount of not less than (\$5,000–\$10,000), and
- full replacement of a section (typically one full length) of pipeline or an improvement that extends the accounting useful life of a section of pipeline by at least 50 years.

Examples of such improvement include

- cement-mortar lining (extends pipe life approximately 30–50 years) and
- structural lining (extends pipe life approximately 50–75 years).

While individual utilities may have different thresholds and different rules, at least one application of these principles dictated that the pipeline condition assessment cost would be expensed if it was later determined that the pipeline condition did not result in replacement or improvement of more than 50 percent of the accessed pipe.

BUDGETING FOR A SYSTEMATIC CONDITION ASSESSMENT PROGRAM

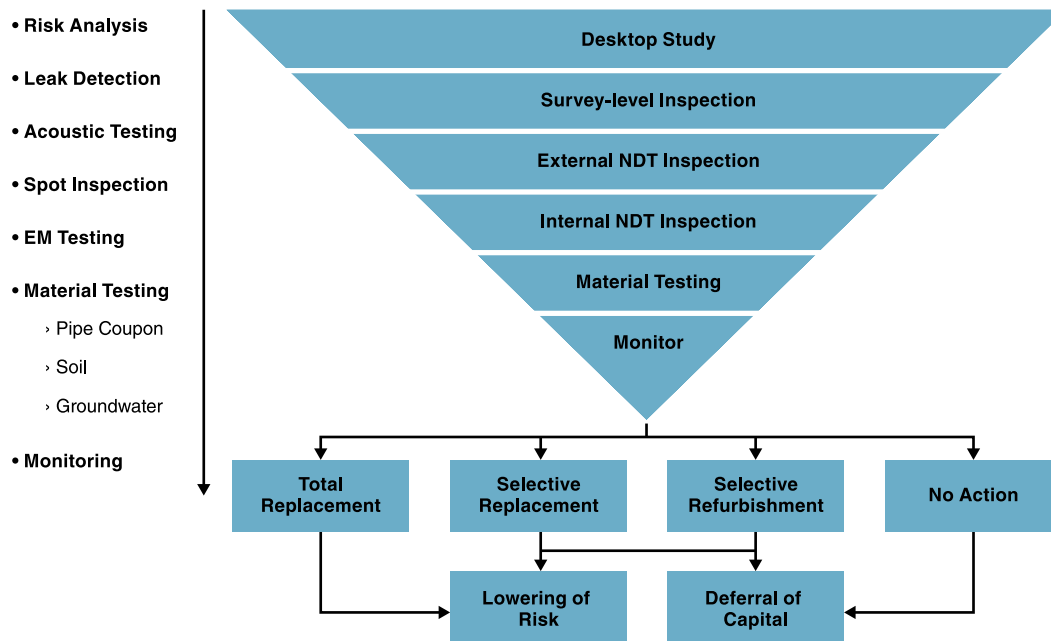
Finding sufficient budget to execute a systematic condition assessment program without proper planning and foresight is often difficult. Often, condition inspection expenses are unknown during budgeting processes as the exact infrastructure to be inspected is undesignated or inspection plans are not yet fully developed. As a result, it is necessary to anticipate, plan, and formulate a systematic program that includes appropriations for operations, in addition to specific projects involving condition assessment.

To this end, leading utilities are developing methods to determine what amount and form of assessment is needed to provide the confidence required to meet their level of service (LOS) targets and execute their capital improvement program and/or repair budgets. Condition assessment planning and budgeting is thus becoming an integral component of master planning processes at water utilities.

Through development of master plans, risk assessments (assessing which assets warrant evaluation) and cost-benefit assessments of condition-inspection technologies are performed. With knowledge of asset types and sizes to be inspected, appropriate technologies are identified and typical costs of an inspection program developed. Combined with risk assessment documenting the consequences of failure, properly quantified in terms of risk-cost exposure, an assessment of cost-effective technologies is produced. Cost-effectiveness is judged by comparing the amount of expense for condition assessment against the benefit obtained (reduction in risk cost). Through this mechanism, budgets can be developed and programmed for future action.

Such budget actions can create a cycle by which systemic condition assessment becomes part of a utility program of asset management improvement. For example, with noninvasive acoustic technologies, utilities may realize a real return on condition assessment costs by simultaneously determining the structural integrity of pipe segments and accurately locating leaks, all without breaking ground or disrupting service, at an assessment cost that provides economic benefit in excess of the financial (direct and indirect) consequences of asset failure.

One practice in use today is the application of the inverted condition assessment pyramid (Figure 2-2) to make decisions about specific buried assets or cohorts (Laven 2014). With the goals of mitigating risk and maximizing capital investments, the process starts with a desktop study and only continues far enough down the pyramid until sufficient



Adapted with permission from Laven (2014)
EM: electromagnetic, NDT: non-destructive technique

Figure 2-2 Progressive condition assessment and resulting actions

information is obtained for a given asset. The pyramid approach helps utilities make an informed choice for repairs, replacement, rehabilitation, or leaving the asset uninspected for a few more decades.

It may not be necessary to follow each of the steps in the pyramid after the initial desktop assessment of risks. For pipes with low risks, no further steps may be needed in the short term. For some high-risk pipes, a utility will find it prudent to move to a detailed condition assessment method and skip over the interim steps. (The selection and application of appropriate condition assessment methods are further discussed in Chapter 3.)

With such an approach, a utility must consider whether condition assessment on specific buried assets provides sufficient information that enables a cost-effective program to be developed over an entire asset inventory. Therefore, the linkage between condition assessment and master planning continues to be the subject of additional research, with the intent being to formulate a generalized roadmap for utility use.

GAINING SUPPORT FROM POLICY MAKERS, THE PUBLIC, AND OTHER STAKEHOLDERS

With a solid business case, gaining support from policy makers, the public, and other stakeholders is possible. Such support is necessary to secure funding and foster public understanding and support for a sustainable program of condition assessment. Often, condition assessment is outside the realm of typical utility-funded activities, so outreach and education are key tactics to employ.

Tactics also may follow other utility investment proposals, such as focusing efforts on value, risk management, and finances. The Utility Branding Network for Water and Waste Water Agencies (2016) identifies the need to create a “compelling argument for investment,” which includes

- a “program title” that succinctly describes the intended objective;
- rules, levels of quality, or desired achievements that are considered acceptable;

- a problem statement that best expresses inability to meet a current level of service, standard, or compliance with a new standard or regulation;
- a method or description of how the problem may be solved—this may be in the form of a specific investment, process, or program;
- communication of capital and operating expenses of the proposed program and whether current budgets and rates already allow the necessary funding;
- an answer to the question “why now?” and why the proposed time frame for action is appropriate—this should include the logic behind the timing;
- sharing considered alternatives in advance to demonstrate an objective, thorough, and transparent process; and
- a critical evaluation of the consequences of failing to implement the proposed program, usually expressed in terms of increased risk or cost. The consequences of not proceeding must be understood and made part of the discussion.

With respect to arguments for a structured, sustainable condition assessment program, improved planning incorporating the results of condition assessment accomplishes two key facets of utility operations. First, long-term replacement plans have been demonstrated (Vause et al. 2013) to be optimized and investment expenditures minimized, as compared to capital plans that do not employ condition assessment. Second, use of condition assessment to improve planning efforts can better align utility performance to desired service standards and help identify which asset types must receive attention in appropriate time frames. These two key results often help policy makers and stakeholders appreciate and understand the importance of supporting assessment programs.

One example of a structured, sustainable condition assessment program is that of the City of Calgary, Alberta. As described by Ellison et al. (2018), for more than 15 years the city has used data from in-pipe, electromagnetic scans to help select water mains for rehabilitation or replacement. Each year, the city scans a small portion of its system, wherein the sections scanned are selected using several criteria that are important to the city’s unique characteristics. This technique has proven most useful for water mains where only a few breaks have occurred and the mains are considered candidates for anode retrofits. If evaluations reveal pipes in a badly deteriorated condition, planned retrofits can be abandoned and mains scheduled for replacement. In addition to these assessments, Calgary also applies data from more than 100,000 soil resistivity readings to infer condition of pipe below ground. This structured program has had the effect of reducing the number of main breaks by one-half over the 15-year period, producing annual savings in repair costs that more than cover the cost of the inspection and retrofit program. At the same time that breaks have been reduced, the main replacement program has also been substantially reduced.

In building a business case for the condition assessment effort, particularly for large-diameter pipe, a utility can expect the following:

- a reduction in the negative impacts of the pipe failure on customers and the environment if not identified proactively;
- a planned approach to needed repair instead of a reactive one;
- a reduction in the costs to complete the repairs and to restore service;
- less impacts on customers because of planning as opposed to a response to an emergency;
- a reduction in the amount of water loss as a result of a planned repair versus a main break; and
- an increased awareness of specific weak areas that alert the utility to be prepared for repair, renewal, or replacement work.

In addition to the direct costs of a planned repair (based on a condition assessment) versus an emergency response to a break, there are other associated costs and/or expenses, such as

- claims against the utility for property damage and/or loss of revenues from businesses;
- a reduction in the utility's anticipated revenues as a result of the break repair; and
- the expense of requiring additional staff time, equipment, and materials to isolate a greater area for the leak repair as opposed to the lesser amount when the job is planned properly.

For a government-owned utility, costs incurred by the public (i.e., the owners of the utility) are to be considered as well. These include costs associated with traffic delays and loss of service, even if no claims are ever filed. Total costs may be much higher than one would imagine. In the case of large-diameter pipe, a study of 30 main failures found a geometric mean of \$500,000 total cost per failure, with the largest costs associated with flooding damage (Gaewski et al. 2007). The time required to close valves appeared to greatly influence costs.

Both the direct and indirect costs of asset failures have been described in greater detail by the Water Research Foundation (Raucher et al. 2017).

SUMMARY

To build support for a condition assessment program, keys to success include

- establishing a solid business case for condition assessment that demonstrates the expense associated with the effort offsets otherwise planned investments, reduces risk costs, or validates asset integrity;
- understanding accounting treatment of expenses and developing a plan in advance of the work that conforms to applicable standards of the utility; and
- anticipating, planning, and formulating a systematic program that includes appropriations for operations, in addition to specific capital projects involving condition assessment.

Taking these steps will improve planning efforts to better align utility operations to desired service standards and help identify which asset types must receive attention in appropriate time frames. A program of this type can also optimize investment expenditures as compared to capital plans that do not employ condition assessment.

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Chapter **3**

Planning a Condition Assessment Project or Program

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This chapter provides an overview of several important subjects to consider when planning a condition assessment project or program, including

- what level of condition assessment is needed,
- how to choose an assessment method for a specific pipeline or location,
- what to consider when planning field work,
- what to consider in communicating the project to the community, and
- how to contract for condition assessment.

LEVELS OF CONDITION ASSESSMENT

The assessment of water mains should be approached like a physician approaches a physical exam. She does not immediately order a full-body scan but rather starts with simple,

inexpensive tests (blood pressure, reflexes, etc.), then moves to more expensive examinations if warranted. Also, multiple tests are performed. No single test provides all the data.

The more serious the possible consequences, the more intensive the examination. Examination of a young, seemingly healthy individual may consist of a few basic tests every several years, whereas as an older person with chronic problems may require many tests performed more frequently.

Similarly, the condition assessment of a pipeline is usually best done progressively, with the results of one inspection determining what additional inspections are appropriate. Higher-risk pipelines are given more attention, and as their condition deteriorates, the assessments become more frequent.

In determining the level of assessment to perform, there are generally four variables to be considered.

1. **The degree of inspection:** Are you ascertaining the general condition of the pipe, or do you want to find small defects?
2. **The inspection coverage:** How much of the pipe is to be assessed?
3. **Pipeline access:** How easy is it to get near or in the pipe with various tools? Can the pipe be shut down and dewatered? How long can it be out of service?
4. **The cost of the assessment:** A utility's willingness to invest in condition assessment should be in some proportion to the perceived risk and the overall value of the asset. An expensive assessment is harder to justify for assets where the replacement cost is relatively inexpensive.

As shown in Figure 3-1, the higher the degree of inspection and the greater the amount of pipe to be inspected, the higher the cost of the assessment.

Additionally, the cost of pipeline inspection is greatly affected by economies of scale, the competitiveness of the marketplace, how easily the pipeline can be accessed, and the development costs associated with the technologies. Unit costs will be lower when longer

Degree of Inspection	Specific Defects	External Direct Assessment, using: • Magnetic flux • Ultrasonic • Electromagnetic • Visual exams • Coupon sampling • Electrical potential measurements	In-pipe condition assessment: • Remote-field electromagnetic scan • Remote-field transformer-coupled scan • Magnetic flux leakage scan • In-pipe leak detection • In-pipe acoustic velocity wall thickness • Other methods, where applicable
	General Conditions	Statistical Studies, using: • Leak/break history • Age • Diameter • Corrosivity and other soil properties • Material class • Pressure and other data	Non-invasive methods: • External acoustic velocity wall thickness measurements • Leak-noise correlation • Other active leak detection • Pipe-to-soil potential measurements • Pressure testing
		Conditions Inferred from Samples	Conditions Directly Measured
Inspection Coverage			

Source: HDR. Modified from Laven et al. (2011)

Figure 3-1 The tradeoffs between costs, coverage, and degree of inspection

run lengths or several pipelines can be inspected with a single mobilization of an inspection technology company.

CHOOSING AN ASSESSMENT METHOD

Pipeline Accessibility Is a Major Consideration

As much as we would like a method that finds all the small defects with no disruption of operations and with only a minor expenditure, technologies have limitations. In general, a tool capable of a high-resolution examination will need to be relatively close to the pipe wall surface. This means excavating to expose the pipe or inserting a tool (or person) inside the pipe.

The ability to access a pipeline is therefore a major consideration. If tools (or personnel) will be used inside the pipe, suitable openings will be required, and operations may be affected. In some cases, existing hydrants, blowoffs, and manways can be used, but in other cases a tool-launching facility will need to be constructed. Some in-pipe tools require a dewatered pipeline, whereas others can be propelled through the pipe using normal water flow. High-resolution assessments typically require tools that are tight-fitting to the pipe bore, so a relatively large access opening is required. If the pipe can be dewatered, some of these tools can be inserted as disassembled pieces through existing manways and assembled from inside the pipe.

For some in-pipe tools, particularly the high-resolution devices, the pipe will need to be cleaned with pipeline pigs before tool insertion. If the pipe is choked with scale (tuberculation), the pigging effort can increase by a magnitude. The pigging is to ensure unimpeded and relatively smooth travel of the tool and also helps to verify that obstructions that block tool passage probably do not exist.

In many cases, multiple contractors may be involved with the inspection. In addition to the pipe inspection company, contractors are often used for constructing access ports and to assist with the pipe cleaning.

Obstructions Must Also Be Considered

The passage of a large tool can be easily blocked by butterfly valves, plug valves, and tight-radius bends. Even when gate valves are present, reducers on both sides of the valves may block passage of the tool. A thorough examination of record drawings and interviews with operations staff is required to determine the potential for such obstructions.

Even small tools can be impeded or lost if the inspection plan does not adequately account for how and where water will flow during the inspection. The flow velocity must be adequate to propel the tool up positive slopes and keep the tool from straying off course. The presence and operability of lateral valves is therefore important.

Progressive Examination Often Saves Money

Often, money can be saved by starting with simpler, less expensive examinations before implementing more expensive tests. Information gathered from the simpler examinations may be sufficient to determine whether the pipe is in relatively good or poor condition.

The general progression for water main condition assessment is as follows, but steps are often omitted, combined, or rearranged as appropriate. Seldom is every step employed.

Step 1. Risk assessment to determine which water mains warrant the most attention

Step 2. Desktop analysis of drawings, soils reports, break/repair history, operational conditions, and staff interviews to determine the general likelihood of a break

Step 3. Site reconnaissance and inspection planning (accessibility, traffic, other utilities)

Step 4. Indirect assessments, including:

- Corrosivity survey
- Corrosion-activity measurements (close-interval survey)

Step 5. Leak detection surveys (external or internal)

Step 6. Low-resolution direct assessments

- Acoustic-velocity measurements of pipe stiffness
- Detection of stress anomalies through analysis of electromagnetic fields

Step 7. Excavations/external exams where leaks, anomalies, or corrosion hot spots are identified or suspected, including:

- High-resolution scanning tools (ultrasonic, magnetic flux leakage, remote-field/broadband electromagnetic)
- Extraction of soil, mortar, and groundwater samples for laboratory examinations
- Electrical measurements to detect corrosion, coating defects, and bi-metallic couples
- Grit-blasting and pit-depth measurements
- Visual and photographic exams

Step 8. Internal physical entry or robotic visual (closed-circuit television, CCTV) inspections, including various scanning and inspection techniques

Step 9. Internal, full-length, high-resolution scans (e.g., magnetic flux leakage or remote-field/broadband electromagnetic)

The results of earlier steps are used to determine the necessity for subsequent actions and to target specific areas. Also, because no single method finds all defects, using multiple methods helps ensure a more complete understanding of pipe condition.

For some pipes, pressure testing may be a suitable alternative to Steps 3 through 7. As discussed in Chapter 14, pressure testing can find rather quickly and economically large weaknesses in large-diameter pipes (areas that may fail catastrophically) but may not find all the small weaknesses.

Opportunity Assessments

Because water mains are not easily accessed, when opportunities to observe either the interior or exterior of a water main occur, they should be considered. Among these opportunities are the following.

- **Repairs.** When mains are repaired, data should be gathered regarding the mode of failure, the properties of the materials, and the condition of the pipe. Photos should be taken, and GPS coordinates should be recorded. Examples of suggested repair reports can be found in various AWWA and Water Research Foundation publications.
- **Service taps.** When pipes are tapped for new service connections, not only is the pipe observed, but coupon samples are often extracted, which can be measured and tested.
- **Failure analyses.** Unexpected, premature, and unexplained failures often merit an engineering/scientific (i.e., “forensic”) assessment, involving laboratory testing of the failed materials and a review of the design and installation of the pipeline and

its operations. Because the results can lead to litigation, these investigations may need to be thorough, detailed, and unbiased.

- **Service interruptions.** A depressurized, dewatered pipeline allows for interior observations that are otherwise more difficult and often not as effective when the pipe is filled. Opportunities arise from tie-ins and other construction work, as well as repairs.

Opportunity assessments can sometimes be a fraction of the cost of other assessments because they take advantage of the traffic control, excavation, shoring, permits, and other logistics that are already in place. However, as with any spot assessments, the results must be interpreted with caution, as the conditions revealed may not be indicative of conditions at other locations along the pipeline.

AVAILABLE TECHNOLOGIES

The materials with which and the way a pipe is manufactured determines which methods are applicable (see Table 3-1). For metallic pipes, a larger range of technologies exists, making use of the electrical, magnetic, and electromagnetic properties of these materials. On the other hand, fewer methods are available for plastic materials (polyvinyl chloride [PVC] and high-density polyethylene [HDPE]), where failures generally stem from small defects that are difficult to find in advance.

The last column in Table 3-1, “Typical Recommended Approach,” shows a suggested sequence of steps that may be used for each material.

Leak Detection Methods

Leak detection methods apply to essentially all pipes, but their degree of success often depends on the material and size of the pipe. Large, massive pipes such as concrete attenuate (diminish) sound more than small metallic pipe, so acoustic leak detection is more difficult. Likewise, sound attenuates on plastic pipe more than on stiffer materials.

Leak noise correlation is a widely practiced method that can be used to help pinpoint leaks using two points of contact. It has been widely used on small-diameter, metallic pipes, but systems are now available that accurately locate leaks on nonmetallic and large diameter mains.

In-pipe leak detection tools can overcome some of these limitations, such as for large-diameter pipes with few appurtenances, and can find very small leaks. These in-pipe tools can also detect gas/air pockets.

Several other leak detection tools and methods can also be used, as discussed in Chapter 7.

Visual and Other Physical Inspection Methods

Physical observations are also useful for many types of pipes and conditions. As described in Chapter 8, visual observations can be accomplished using CCTV cameras mounted on robotic crawlers, push-in probes, miniature submarines, and other platforms. These inspections often include laser and sonar instruments for measuring various physical conditions. For larger pipelines, physical entry (“manned” inspections) by trained personnel can be useful—not just for observation, but for performance of various physical tests from inside the pipe, as described in Chapter 9.

A word of caution: looks can be deceiving. Although CCTV is widely used in wastewater and other gravity pipes, the defects that cause pressure pipes to fail are often not easily observed. In water mains, CCTV can determine the presence (or absence) of lining

Table 3-1 Available inspection technologies for pressure pipe

Method	Soil Corrosivity Surveys	Acoustic	Remote Field Electromagnetic	Ultrasonic	Magnetic Flux Leakage	Broadband Electromagnetic	Other	Typical Recommended Approach
Description	Various electro-magnetic, electrical, and laboratory methods characterize the corrosivity of soils, detect/measure corrosion activity, and assess effectiveness of corrosion protection/cathodic protection	Acoustic velocity: pipe wall stiffness is calculated from the speed of sound transmission Acoustic monitoring: alerts and pinpoints the location of wire breaks	Changes in electromagnetic signals indicate broken wires, corrosion pits, and changes in wall thickness and stress anomalies	Reflection of sound waves is used to measure the thickness of various types of materials. Tool must have direct contact or liquid coupling with material being measured	Changes in magnetic fields are used to detect corrosion pits and other defects. Tool must be at constant, close distance from pipe wall	Changes in electromagnetic signals indicate corrosion pits and changes in thickness. Scanner held near pipe, but works through coatings, linings, and scale	Sampling of pipes for various physical tests Manned entry for visual and sounding (delamination testing) Petrographic (microscopic) examinations of concretes and mortars	GENERAL APPROACH (all pipe types): 1. Statistical analysis of available data 2. Risk prioritization (likelihood and consequence of failure) 3. Records review (leak/break repairs, drawings, specs, reports, soil info) 4. Site reconnaissance (accessibility, traffic conditions, other utilities) 5. Inspection planning (shutdowns, bypass, permits, alternatives) 6. Leak detection and/or field condition assessment inspection

(continued)

Table 3-1 Available inspection technologies for pressure pipe (continued)

Method	Soil Corrosivity Surveys	Acoustic	Remote Field Electromagnetic	Ultrasonic	Magnetic Flux Leakage	Broadband Electromagnetic	Other	Typical Recommended Approach
Asbestos Cement (AWWA C402)	Assess potential for AC (concrete) deterioration (pH and sulfates)	Acoustic velocity can detect gross deterioration	n/a	n/a	n/a	n/a	Testing of samples: • Phenolphthalein stain • SEM/EDS • petrography	1. Tests of opportunity samples from repairs and service taps 2. GIS mapping of soil data, breaks, and condition 3. Targeted assessment of high-consequence pipes
Prestressed Concrete Cylinder Pressure Pipe (AWWA C301 and C304)	Assess potential for metal and concrete deterioration Detect active corrosion	Acoustic monitoring for detection of wire breaks. Acoustic velocity can be used for prioritization of other assessments.	Used to detect broken wires	n/a	n/a	External and internal spot assessments	Internal sounding to detect delamination Internal visual (manned entry or CCTV) External direct assessment Petrographic analysis of mortar/concrete	1. Risk analysis based on pipe type, manufacturer, wire type, year of manufacturer, corrosion 2. Manned entry/sounding (if feasible) 3. Electromagnetic scanning 4. Acoustic monitoring
Non-Prestressed Concrete Pressure Pipe (AWWA C300, C302, and C303)	Assess potential for metal and concrete deterioration Detect active corrosion	n/a	Emerging method to detect broken bars and cylinder corrosion	n/a	n/a	External spot assessments. Emerging method for internal scanning	Internal sounding to detect delamination Internal visual (manned entry or CCTV) External direct assessment Petrographic analysis of mortar/concrete	1. Corrosivity survey 2. External direct assessment where corrosion risk is highest 3. Manned entry examination 4. Electromagnetic scanning

(continued)

Table 3-1 Available inspection technologies for pressure pipe (continued)

Method	Soil Corrosivity Surveys	Acoustic	Remote Field Electromagnetic	Ultrasonic	Magnetic Flux Leakage	Broadband Electromagnetic	Other	Typical Recommended Approach
Ductile Iron Cast Iron (AWWA C150 & C153)	Assess corrosivity to iron Monitor corrosion activity	Acoustic velocity can detect gross deterioration	Detailed internal scan of pipes and external spot assessment. Works with cement mortar and tuberculation	Used for external spot assessments	Internal scanning of non-CML lined pipes. External spot assessments.	External spot assessments. Emerging method for internal scanning	Petrographic analysis of mortar	1. Corrosivity survey 2. Remote field electromagnetic
Steel (AWWA C200)	Assess potential for metal and concrete deterioration Monitor corrosion activity	Acoustic velocity can detect gross deterioration	Used for detailed internal scan of pipes. Works with cement mortar and tuberculation.	Used for external spot assessments	Internal and external scanning of both CML and non-CML pipes	External spot assessments. Emerging for internal scanning.	Petrographic analysis of mortar	1. Corrosivity survey 2. Pipe-to-soil potential; cathodic protection assessment 3. Remote field electromagnetic or magnetic flux leakage
Copper	Assess potential for metal deterioration	n/a	Used for detailed internal scan of pipes	n/a	n/a	Potential for detailed scan of pipes	Forensic examinations of failed pipes Electrochemical noise monitoring	1. Evaluate construction methods and standards 2. Evaluate soil corrosivity 3. Forensic exams of failures
Plastic Pipes (HDPE – AWWA C906) (PVC – AWWA C900)	n/a	n/a	n/a	n/a	n/a	n/a	Forensic examinations of failed pipes, using laboratory and mechanical tests	1. Review of drawings, specs, and inspection records 2. Forensic examination if early or frequent failures have occurred

Source: HDR

AC: asbestos concrete, CCTV: closed-circuit television, CML: cement mortar lines, GIS: geographic information system, HDPE: high-density polyethylene, n/a: not applicable, PVC: polyvinyl chloride, SEM/EDS: scanning electron microscopy with energy-dispersive spectroscopy

and the degree of scaling, but the integrity of the pipe itself will generally not be discernible. Moreover, even when the pipe is visible, the degradation is often hidden. Graphite and other corrosion products obscure the deterioration of iron pipes. The deterioration of asbestos cement (AC) and concrete pipes is similarly hidden.

Inspection Limitations

It is important to understand not only the capabilities but also the limitations of the various inspection methods: what sizes and types of defects might be missed; has the method been verified by independent, third-party verifications (dig-ups); where are the blind spots? Several methods, for instance, have difficulties finding defects near pipe joints, and irregularities such as riveted joints may produce noisy data. In many cases, the amount of damage that is detected will be understated, because no method detects every type of defect.

PLANNING OF FIELD WORK/COMMUNICATIONS

Depending on what methods are employed, planning can range from simple to complex. In many cases, work occurs in roadways, so safety is a concern, and traffic control and associated permits may be required. Generally, the larger the pipe, the greater the effort required to plan and execute the work.

If tools will be inserted within potable water mains, a plan is necessary for how water quality will be protected. Only tools designated for potable water should be used, and they will need to be disinfected before entering the system. It is likely that sediment in the pipe will be stirred up, which will cloud the water. If a tuberculated main is being scanned, greater thought is required; disturbance of these scales can lead to longer-range “dirty water” issues and possible concerns about release of contaminants that may be concentrated in the scales. Most of these issues are solved by isolating the main before the work is performed and flushing the main after. This may include closing service lines so customers do not receive turbid water and possibly flushing the services upon completion of work. In general, the processes and procedures should be similar to how the utility handles main repairs.

A bypass piping system can be installed as a way of providing continued water supply to customers while the assessment is underway, preventing worry about water contamination. Such systems are typically laid along both sides of the road with provisions for vehicle passage at driveways and other crossings. The systems are disinfected and fully tested before they are placed into service. [AWWA M28, *Rehabilitation of Water Mains*](#), provides additional information.

Customer notifications are essential for any work where shutdowns will occur or where water turbidity is a possibility. When properly informed of the purpose of the work, most customers will appreciate that the utility is performing the assessment and will often find the “high-tech” work interesting. Communications may be by letters, community meetings, and (of course) e-mails and the Internet. Providing customers with phone numbers, e-mail addresses, and other means of communicating their concerns and questions is also important. Providing the customer with free bottled water may also be helpful in generating goodwill.

For large pipes, pipes in busy streets, and non-tethered tool insertions, the inspection company, the engineer, and various utility managers should meet to discuss the various risks and determine appropriate contingency plans. While the work is not dramatically different from work that the utility performs routinely, roles and responsibilities need to be understood. As the adage goes, “failing to plan is planning to fail.”

Logistical Considerations for Performing Internal Inspections

When employing any technique where a tool is inserted inside the pipe, several logistical issues must be considered.

- **Shutdown, isolation, and dewatering of pipeline.** One of the most important considerations for selecting and performing internal inspections is whether the main can be shut down, isolated, and dewatered. This will dictate what methods can be practically deployed to inspect the pipeline interior. Associated concerns include water discharge requirements and permits.
- **Access points into pipeline.** Another significant consideration is whether there are access ports, flanges, manways, or launching stations on the pipeline. Having to install new access points adds significant cost to the condition assessment. It is also important to know where the access points are located and how accessible they are. Associated concerns include traffic control, shoring, and permit acquisition.
- **Pipeline operating conditions.** For inspection of operational pipes, operating pressure and flow velocity are important considerations. Pressures above 200 psi can be problematic for some tools. For devices that are propelled by water flow, velocities that are too low can cause the tool to stall, and velocities that are too high can result in poor data collection.
- **Constraints due to pipeline configuration.** The pipeline's physical configuration (size, alignment, potential obstructions) has to be considered in relation to the tool or technique that is proposed.
 - *Pipe size.* Generally, physical (manned) entry is practical down to about 36-in. diameter for pipelines. Entry into smaller pipes is possible, but there are increased safety concerns. Manned-entry inspections must always be carefully planned and thoroughly reviewed.
 - *Pipe bends and pipe slope.* Changes in direction both horizontally and vertically can hinder internal inspections by limiting the distance covered from an access point. Cable drag increases significantly at pipe bends. Normally, a tethered tool can be safely pulled through no more than about 300° of bends (e.g., three 90° elbows). Sharp, short-radius bends can block tool passage or damage cables.
 - *Pipe length.* Long travel distances may make manned entry difficult, and tethered tools will always be limited by cable length as well as the number of bends and operating conditions (flow and pressure).
 - *Obstructions.* Internal obstructions created by valves, appurtenances, debris, and scale buildup (tubercles) can limit the length of internal inspections or manned entry. For example, butterfly valves and other non-full-bore valves may be impassible for large tools and pose a risk that equipment will get stuck. Cleaning can address the issue of scale buildup, but cleaning requires an additional step and perhaps an additional shutdown. Complaints of discolored water may occur if the cleaning is not well managed.

Health and Safety Considerations

As with all utility activities, health and safety issues are the most important considerations. If the inspection cannot be performed safely, without risks to consumer health, then it needs to be reconsidered.

Many utilities may be able to rely on their existing standard processes and procedures, but exactly who is responsible for what must be determined in advance. Often staff from several departments need to be brought together with one or more outside contractors to finalize the plan and ensure regulatory compliance. Among the issues to be considered are

- the closing of line and lateral valves to isolate the main and customer impacts;
- lock-out/tag-out procedures;
- disinfection of tools and materials that contact water or are inserted in pipes;
- traffic control, barricades, shoring, and other worker protection;
- confined-space entry procedures—air monitoring, personnel retrieval, and permits; and
- disinfection, flushing, and testing of mains and laterals post inspection.

Generally, inspection tools used in wastewater mains should not be used in water mains. Most inspection companies understand this and segregate tools accordingly, but the question should always be asked.

CONTRACT GUIDELINES

Unlike video inspections performed on sewer mains, water main condition assessment is never a commodity. Seldom are similar services offered by competing companies. Even where two companies offer similar-looking work (e.g., electromagnetic scanning), it is important to understand the differences in what each company provides, both in terms of the final product and how much field support will be required. Tools that appear to be similar can in fact be very different in their ability to detect pipe defects. Equally important is the amount of skill and effort that is devoted to interpretation of results. For most technologies, a very well-trained technician is needed to take the data produced by the device and translate them to useful information.

In soliciting work, a “request for proposals” (RFP) is thus a more appropriate means of obtaining services than a “request for bids.” If selection is done on a “low-bid” basis, the utility is likely to get the least value as well as the lowest cost. An RFP should include

- a description of what the utility is trying to accomplish;
- project requirements, including
 - the contractor’s responsibilities and
 - the utility’s responsibilities;
- constraints, including permits;
- proposal requirements; and
- evaluation criteria and method of selection.

Examples of RFPs can often be obtained from consultants, other utilities, and the technology companies themselves.

In evaluating proposals, the greatest attention needs to be paid to the experience and expertise of the company, its technology, and the information it will provide. Some technologies have been introduced to the market without being thoroughly tested, whereas other technologies have undergone years of independent tests, including tests by the Water Research Foundation and the US Environmental Protection Agency (USEPA), where pipes have been exhumed to verify both positive findings (i.e., the presence of defects) and negative findings (i.e., the absence of defects). Proving that a technology can find a defect is less important than proving that it won’t miss a defect.

While most utilities have a “can-do” attitude and very smart technical people, it may be helpful to also employ a consultant who is well versed in this work. Websites and company literature often do not provide enough information to distinguish the apple from the orange and know which one is better for a particular situation.

SUMMARY

Many issues must be considered in planning a condition assessment project, including selecting the methods that are most appropriate for the pipelines and implementing them effectively. Method selection hinges on the goals of the assessment, how readily the pipe is accessed, what obstructions might exist within the pipe, and how much the utility is willing to pay. Investments in condition assessment should relate to the perceived risk of a pipeline and the expected benefit of the assessment.

As with all field work, safety is the prime consideration, and for work on potable water systems, maintaining sanitary conditions is a foremost concern. Effective customer communication is a priority; good communication builds and maintains support for the program and helps protect the utility's reputation.

Because water main condition assessment is both relatively new and rapidly evolving, utilities often lack the necessary knowledge to confidently plan and execute these projects. While this manual helps to fill the gap, there is no substitute for experience, which is available through the AWWA Water Main Condition Assessment Committee.

REFERENCE

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Chapter 4

Desktop Condition Assessment

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A desktop assessment generally precedes the field inspections that are described in later chapters. The term “desktop” means a review and analysis of available records and documents, including system data, repair records, drawings, geotechnical reports, failure analyses, and other *existing* data. Because these data come from utility files, a desktop assessment is relatively inexpensive compared to the collection of new data. The collection of new data can also be disruptive, involving service interruptions and other community impacts. Desktop condition assessments help determine what additional data and assessments are worthwhile.

The purposes of desktop assessments are to

- calculate and forecast system performance (break rates and service levels);
- estimate the remaining useful lives of assets and determine appropriate renewal rates;
- determine which mains represent the highest risks to the utility based on likelihood and consequence of failure; and
- determine which of the high-risk mains are candidates for physical condition assessment.