Pipe Location and Leakage Management for Small Water Systems
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Pipe Location and Leakage Management for Small Water Systems

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# CONTENTS

LIST OF TABLES ................................................................................................................... vii

LIST OF FIGURES ................................................................................................................ ix

FOREWORD .......................................................................................................................... xi

ACKNOWLEDGMENTS ....................................................................................................... xiii

EXECUTIVE SUMMARY ................................................................................................... xv

CHAPTER 1: SMALL SYSTEM CHARACTERISTICS ......................................................... 1
  Introduction .................................................................................................................. 1
  Small System Characteristics .................................................................................... 1
  Issues With Nonmetallic Pipe .................................................................................. 3

CHAPTER 2: APPROACH AND KEY FINDINGS .................................................................. 5
  Tasks ......................................................................................................................... 5
    Task 1: Project Initiation ....................................................................................... 5
    Task 2: State of the Industry Review .................................................................... 5
    Task 4: Preparation of Presentation Materials ................................................... 12
    Task 5: Validating the Presentation Materials .................................................... 13

CHAPTER 3: PRESENTATION MATERIALS ....................................................................... 15
  Intent ......................................................................................................................... 15
    Provide Assistance on Knowing if a Water System Has a Problem .................... 15
    Provide Guidance on What to Do to Get Started ............................................. 16
    Understanding the Technology and How to Use It ......................................... 16
  Content .................................................................................................................... 17
    Introduction Presentation ..................................................................................... 17
    Pipe Location Presentation .................................................................................. 17
    Leak Evaluation Presentation .............................................................................. 17
    Leak Locating Presentation .................................................................................. 18

CHAPTER 4: REFERENCE MATERIALS ............................................................................ 21
  primary References ................................................................................................. 21
    Pipe Location ....................................................................................................... 21
    Water Loss Evaluation ......................................................................................... 21
    Leak Locating ...................................................................................................... 21
    Rural Water Associations ..................................................................................... 22
  Video References ................................................................................................... 22

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS ............................................. 25
  Conclusions ........................................................................................................... 25
  Recommendations ................................................................................................. 25
APPENDIX ................................................................................................................................... 27
   Workshop Evaluation Summaries.......................................................................................... 27
   Survey Totals ....................................................................................................................... 27
   Examples of Responses to Open Ended Questions............................................................ 28
   Tables of Locating Devices ............................................................................................... 29
   Pipe and Appurtenance Locating Equipment ..................................................................... 29
   Leak Detection Equipment ............................................................................................... 31

REFERENCES .......................................................................................................................... 33

ABBREVIATIONS ...................................................................................................................... 39
LIST OF TABLES

1.1 Comparisons of large and small systems ................................................................. 2

4.1 Example video references ......................................................................................... 22
LIST OF FIGURES

1.1 Percentage of systems with customer meters by size of system ................................................2

2.1 Vibration induced PVC pipe locator ..........................................................................................10

2.2 Innspектор 007 ..........................................................................................................................11
OREWORD

The Water Research Foundation (WRF) is a nonprofit corporation dedicated to the development and implementation of scientifically sound research designed to help drinking water utilities respond to regulatory requirements and address high-priority concerns. WRF’s research agenda is developed through a process of consultation with WRF subscribers and other drinking water professionals. WRF’s Board of Trustees and other professional volunteers help prioritize and select research projects for funding based upon current and future industry needs, applicability, and past work. WRF sponsors research projects through the Focus Area, Emerging Opportunities, and Tailored Collaboration programs, as well as various joint research efforts with organizations such as the U.S. Environmental Protection Agency and the U.S. Bureau of Reclamation.

This publication is a result of a research project fully funded or funded in part by WRF subscribers. WRF’s subscription program provides a cost-effective and collaborative method for funding research in the public interest. The research investment that underpins this report will intrinsically increase in value as the findings are applied in communities throughout the world. WRF research projects are managed closely from their inception to the final report by the staff and a large cadre of volunteers who willingly contribute their time and expertise. WRF provides planning, management, and technical oversight and awards contracts to other institutions such as water utilities, universities, and engineering firms to conduct the research.

A broad spectrum of water supply issues is addressed by WRF's research agenda, including resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide a reliable supply of safe and affordable drinking water to consumers. The true benefits of WRF’s research are realized when the results are implemented at the utility level. WRF's staff and Board of Trustees are pleased to offer this publication as a contribution toward that end.

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EXECUTIVE SUMMARY

OBJECTIVES

The goal of this project was to create guidance material to assist small system operators in the essential functions of locating their buried infrastructure and identifying and pinpointing leaks. Communicating this information immediately suggested to the researchers that a broader effort beyond a written report was required to reach out to small sized utilities. The primary output of the project is not this report but a series of presentation materials suitable for a workshop setting. This publication is a supplement to the presentation material that outlines project issues and how the research progressed as well as being a reference for other materials that can be used by small system operators and trainers.

Of course, the challenge of managing water system assets that are “out of sight” is not limited to small utilities. In order to maintain pipes, valves, connections, and service lines, all water system operators need to know their physical location and condition, particularly if they are beginning to fail. The inevitable deterioration of the underground pipe network requires increasing awareness of piping and the controlling valve location to limit damage in addition to having the ability to identify when and where failures are occurring. Consequently, resources used by utilities, large and small, have been researched as part of the project and subsequently tailored to suit small systems.

Small systems do have unique challenges. Location and leak issues are magnified for small systems where resources may be limited. For example, smaller systems may find that one or two persistent undiscovered leaks can threaten its limited water supply or cause financial hardship. Owing to budget limitations, highly sophisticated locating and monitoring equipment that can help may not be affordable. Labor is an issue; some operators of small systems also manage other operations including wastewater, parks and recreation, trash, highway, and other municipal functions. Small systems are more prone not to be metered at the customer location though many do see the value of customer metering.

The presentations materials prepared (and described in Chapter 3) were designed to equip operators with knowledge of basic line locating and leak locating. It is strongly suggested the workshops be augmented with first hand demonstrations of equipment that appears readily available from vendors and distributors of the equipment. Workshops that included such demonstrations were well received. They were not only informative and complimentary but break up training fatigue that can occur in an extended classroom setting.

The researchers chose not to provide a program focused on leak locating techniques without addressing how to know if leakage is a significant issue for a utility in the first place. It was decided at the proposal stage to provide small utilities with a means to quantify their leakage in order to have an improved sense of how much investment should be made in limiting water loss. The challenge of quantifying leaks can rely on the AWWA Water Audit. Because a significant difference between water production and estimated or measured customer consumption is not always explained by leaks, the AWWA M36 (third edition, 2009) is a tremendous resource. With full descriptions of types of non revenue water and procedures and techniques to address the control of water losses including leak detection approaches, it is an essential reference. The project team did modify the M36 approach for small systems, but tended to verify the spirit of the approaches taken. The modifications for small systems in the
presentation material emphasized the district metering approach, monitoring night flow, and the process of step testing.

A vital issue for the project is effectively communicating the information gathered to the end users, the small system operators. While reports are valuable, most small system operators receive information from their primacy agency and local assistance organizations through training programs, technical assistance, and communication items (newsletters, etc.). Training is often required to maintain operator certification and organizations that provide training are always looking for good content. Linking the project report or web content to training and technical assistance efforts is essential for application of the project results.

BACKGROUND

The project approach consisted of six steps:

Task 1: Project Initiation

Work began with organizing a broader team of people who interact with small systems and inviting the Project Advisory Committee into the process. Phone conferences were instrumental in the project to initially establish expectations and direction. Many of the team members were trainers themselves and brought their own skills and observations to the process: The majority of the workshop sites were set up by the individual team members, some of whom participated in presenting the material.

Task 2: State of the Industry Review

This task largely consisted of a literature review, examination of training materials, and a first-hand examination of equipment utilized to find buried assets. The literature review examined a variety of available reports for information on pipe locating, water auditing, and leak location. The review focused on techniques and technologies for locating pipes and leaks for different pipe materials, especially nonmetallic (plastic and asbestos cement) pipe. The researchers identified some key literature that provides solid basic information (reference in Chapter 4). Some product and training videos were identified available on CD or YouTube and reviewed. This suggests a potential for a more generic avenue for future training materials for small system operators.

Task 3: Review of Special Needs and Limits of Small System Operations

As technical research was being conducted, the project team coordinated with various small systems related associations to identify challenges and opportunities associated with small systems training. This early effort helped to build an effective series of presentations near the start of that process. Experience has shown that the most effective methods for reaching small system operators are:

- Training programs that are required to maintain operator certification
- Technical support offered by state rural water associations, state primacy agencies, large water systems, and consultants
- Communication efforts from state rural water associations and primacy agencies
Workshops supplemented by hands on training of equipment

The project team also explored other methods of presentation including a draft YouTube presentation on listening for leaks. This appears to be a viable future means of reaching small system operators.

Task 4: Preparation of Presentation Materials

The information gathered from Task 2, blended with feedback from Task 3, generated an introductory slide presentation and three PowerPoint training modules. Module 1 addressed pipe locating. Module 2 addressed the evaluation of leak loss. The final module dealt with leak locating devices and strategies. All four slide presentations include in the notes portion of each slide pertinent training points, tips, or anecdotes.

Task 5: Validating the Presentation Materials

Task 5.1: Workshops with Small Systems via Related Agencies

Once the draft product was produced, it was copied and circulated to the project team for input. The project was previewed at DSS and the Montana Training Center and subsequently tested in six separate, dedicated workshops. In most cases the workshops were directly organized by a technical assistance provider to small systems. Evaluations were conducted at each workshop and the results were used to modify training materials for subsequent workshops. A meeting with PAC members was held in September 2012 to highlight the final results and some of the key features of the modules.

Task 5.2: Selected Field Testing with Small Systems

As innovative techniques for pipe locating and leak detection were identified, American Water provided the field testing of equipment that offered potential to small system operators. There were not a significant number of new items to review. Equipment that had potential for being applied in some cases were an insertable video camera that also listened for leaks, ground penetrating radar, and the use of a conductive wire that can be inserted in water lines to be subsequently be located. During informal testing with other pipe locating units, divining rods proved to be successful; this was not surprising to the researchers and many of the operators.

Task 5.3: Communication Discussions

Following team review of presentation materials, validation of training materials relied on workshop feedback from participants. Based upon evaluations provided at the workshops, the material, supplemented by demonstrations, was judged highly effective. Analysis of the feedback from operator ratings (a summary of evaluations is provided in the Appendix) helped to identify weak spots and areas for improvement.
Task 6: Preparation of Final Manual and Training Presentation Material

The workshop materials have been submitted in advance of the writing of this report for PAC review. A key element of this report is a list of resources that should be made available to future audiences.

RESULTS AND CONCLUSIONS

One of the best ways to reach small system operators is through local technical assistance providers. Organizations employed included state Rural Water Associations, the Rural Community Assistance Partnerships, and an Environmental Finance Center. These organizations have day to day contact with small system operators and are known and trusted sources of information. Also, the only practical way to reach a large number of small systems is through this established network of technical assistance providers. While the training materials are fairly complete, it is recommended that “train the trainer” workshops are held for these providers.

Effective training workshops should have a hands-on component and therefore it is essential that presentations be supplemented by vendor or consultant demonstrations of equipment. As long as the commercial aspects of demonstrations are held in check, this is an effective compliment to the material provided.

APPLICATIONS AND RECOMMENDATIONS

It is recommended that work continue on exploring methods to locate buried pipe and undetected leaks on nonmetallic materials. While there is some improvement in locating technologies, there remain considerable differences in detection between metallic and nonmetallic pipe. There are some indications that improvements are being made in acoustic sensing to locate leaks on plastic pipe. Small system users with plastic pipe should examine a number of leak locating devices to test their ability to detect such leaks.

It is recommended that the Water Research Foundation consider a project to more carefully evaluate the use of divining rods. Numerous utilities and the research team have found that the units work for them though the science and the evidence of their functionality is refuted. There is a reason why many utilities use these simple devices with some level of success. The researchers did not identify a non-invasive technique to be more effective on non-metallic pipe.

Finally, the researchers would urge small system operators (and all operators) to place durable tracer wire or marker balls along non-metallic pipes that they are currently installing. Effective proactive marking combined with good mapping will be the most effective way to extend the location problem beyond pipes that are already in the ground. The plastic pipe industry should make a better effort to encourage the use of tracer wire and other buried markers in their standards and published materials.

MULTIMEDIA

Four PowerPoint presentations including an introduction presentation, a pipe locating presentation, a leak evaluation presentation, and a leak locating presentation are located on the 4144 project page under Project Resources/Presentations. They are also described in Chapter 3.
CHAPTER 1: SMALL SYSTEM CHARACTERISTICS

INTRODUCTION

The goal of the project was to create output to communicate information to assist small system operators in locating pipelines and leaks on the pipelines. The primary documentation for this project is not this report but a series of PowerPoint modules that include speaker notes to assist trainers to educate small system operators.

This report is organized into 5 brief chapters. This first chapter outlines some of the challenges for small system operations based upon observed and documented characteristics. The second chapter outlines the research approach taken to generate material and key findings. Chapter 3 discusses elements of the presentation material. Chapter 4 contains a description of references that will be of use to the small system user. Chapter 5 follows with general conclusions and recommendations on how this information can be sustained and passed to small system users. Key reference materials are found in Chapter 4 and lists of equipment are found in the Appendix.

SMALL SYSTEM CHARACTERISTICS

A great deal has been written about the problems that small water systems face in providing their customers with safe, adequate, reliable and affordable water service. An AWWA Journal article from 1992 (Cromwell et al. 1992) still echoes that “a large number of aging systems are encountering performance problems that were not apparent for the first 30, 40, 50 years of operation. Similarly, there are 5-, 10-, and 20-year old systems that are not showing any deficiencies but that are inevitably destined to the same end.”

The EPA Report, National Characteristics of Drinking Water Systems Serving Populations under 10,000 (July 2011) provides some insights into the makeup of small systems. They cite 2008 Safe Drinking Water Information Systems data that indicates 92% of US drinking water systems serve populations less than 10,000 and serve only 18% of the population using a community water system. The majority of small systems that serve more the 500 people are public. Most systems serving less than 500 are largely private. (The researchers encountered systems both over and under 500 customers during workshops.) The data also indicated that the smaller the system, the more likely that water source was groundwater while the larger the system the more likely the source will be purchased water or surface water supply. This is a significant consideration as surface water and purchased water tend to have a higher cost which places greater cost on the leaking water while small groundwater systems may be confronted with running out of water from chronic leakage that can drain their resource.

The number of service connections per mile of main is substantially higher for large private utilities serving more than 10,000 customers (311 per mile). Public systems of all sizes and private systems serving less than 10,000 range from 31 to 80 customers per mile of main with density generally decreasing in smaller size systems. This suggests that financial resources to maintain each mile of main are potentially more of a burden on the smallest systems. Unfortunately the statistics on leakage in the EPA report are categorized usually as an antiquated terminology of “unaccounted for water” which is a term subject to misuse. In terms of a pipe
network, a branching system of a small system is inherently less redundant than a large system grid.

Generally larger systems are more inclined to meter but even the majority of systems serving 100 to 500 people have residential metering. Metering is a key component to understanding what portion of a water supply is getting to the customer. There is no data on the accuracy or age of the meters but it is speculated that smaller systems do not replace meters as frequently (Figure 1.1).

The AWWA M36 manual identifies special issues for small systems. A brief summary of differences between large and small systems as presented in the document is provided in Table 1.1:

<table>
<thead>
<tr>
<th>Typical Characteristics</th>
<th>Large Systems</th>
<th>Small Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Water</td>
<td>Often surface water from large reservoir, river or lake network.</td>
<td>Most small systems rely on groundwater or a mix of surface water and groundwater from scattered small lakes, streams and wells.</td>
</tr>
<tr>
<td>Reliability</td>
<td>Large dams and reservoirs exist on many resources providing storage reserves to maintain reliability.</td>
<td>Many groundwater supplies are shared with high demand agriculture industry. Certain large aquifers are under stress from overpumping.</td>
</tr>
<tr>
<td>Ability to meet peak demands</td>
<td>Can rely on water stored in reservoir infrastructure to help supply peak periods.</td>
<td>Must typically increase (groundwater) pumping to meet peak demands.</td>
</tr>
<tr>
<td>Water Distribution System Configuration Reliability</td>
<td>Redundancy usually exists to provide enhanced reliability; grid piping network is typical.</td>
<td>Sole source often exists, offering less reliability; branching pipe networks are common.</td>
</tr>
<tr>
<td>System needs</td>
<td>Many systems in urban and older suburban areas are aged and require significant upgrades.</td>
<td>Systems reported to have more than three times the per household infrastructure needs than large systems (cost to customer).</td>
</tr>
<tr>
<td>Engineering Services</td>
<td>Many systems conduct engineering programs with in-house staff or a mix of staff and engineering consultants.</td>
<td>Systems often have greatly limited or no in-house engineering staff; work is typically outsourced to engineering consultants.</td>
</tr>
</tbody>
</table>

Locating buried infrastructure may actually be less difficult for very old small systems that will be made of easy to locate metallic material. Mains, services, valves, curb stops along

---

1 This reflects a portion of a table provided in the AWWA M36 Manual (third edition, 2009) page 198.
with curb and valve boxes that are metal are readily found by locators. Metallic locators have been in use for many years and with advances in electronics have a high success rate. Leakage can be tracked on metal pipe using acoustic equipment with far more effectiveness than systems composed of newer non-metallic pipes.

**ISSUES WITH NONMETALLIC PIPE**

With the advent of cement and plastic pipe materials about 50 years ago, finding lines and leaks became more challenging. Nonmetallic materials do not conduct electricity or magnetic fields and tend to attenuate vibration from leaks. The use of tracer wire or location tape was not a standard pipe locating aid practiced until more recently. The tracer wire installed years ago was not a robust material (often simple telephone wire) that can be easily compromised. A quick survey of the AWWA manuals for PVC, polyethylene (PE) and cement pipe show that only the recent PE pipe manual (AWWA 2006) even mentions locating tape or wire. A number of utilities now employ high strength tracer wire owing to the failures of thinner, weaker materials.

Locating leaks in plastic and asbestos cement pipe is far more challenging than in metal pipelines. A WaterRF research project by the National Research Council of Canada (Hunaidi et al. 1999) identified the frequencies of plastic pipe leaks at less than 50 HZ with an amplitude of the sound diminishing at a rate of about 25 decibels per 100 meters (8 decibels per 100 feet). In response to the need, many acoustic monitoring companies have subsequently improved their detection of lower frequencies but the rapid loss of sound in the plastic pipe reduces the opportunity to detect plastic pipe leaks at long range. A Water Research Foundation project by American Water (Hughes 2011) noted that the transitions between materials and use of repair clamps provide further obstacles to acoustic leak detection.
CHAPTER 2:
APPROACH AND KEY FINDINGS

TASKS

The project advanced very much as originally proposed. The major change was a greater emphasis on the workshops to help refine the key output.

Task 1: Project Initiation

At the onset of the project, a team meeting of the full research team (the investigators and members representing the Colorado Rural Water Association, Montana State Water Center, New Mexico Environmental Finance Center and the Texas Water Development Board) met by phone. The team reviewed the approach and each of the members spoke enthusiastically about providing a training site. Subsequent meetings reviewed presentation content and the workshop experience.

The team was expanded to include a representative from the Rural Community Assistance Partnership (RCAP) following a presentation about the project at RCAP annual conference on November 30, 2010. Wayne Cannon of the Ohio RA was selected and joined the team. Steve Cavanaugh of Cavanaugh Associates joined the team as an advisor in light of their company’s training experience in the Carolinas. Mark Mathis departed the Texas Water Board to work for the Aqua Water Supply Corporation (AWSC, Bastrop, TX) but continued to work on the team and later sponsored a workshop at AWSC’s offices. Email was the primary communication tool for the team as workshops were scheduled.

Given the emphasis on communication in the project, the Water Research Foundation permitted alternating between written quarterly reports and quarterly phone conferences with the project manager and the PAC. The first report was provided in a presentation on January 14, 2011 and culminated in September 2012 with a final PAC meeting in St. Louis.

Task 2: State of the Industry Review

Literature studies were largely completed early in the project although monitoring for reports did continue. Field testing of equipment is routinely practiced at American Water and many techniques were reviewed directly by the research team.

Task 2.1: Literature Review for Pipe Location and Water Loss Management

Pipe Location. The literature review covering the various pipe locating tools did not reveal significant resources. The recently published WaterRF report on the subject, *Underground Facility Pinpointing- Finding a Precise Locating System for Buried Underground Facilities* (Farag and Vetter 2011) was reviewed. The report prepared by GTI provided an independent evaluation of a variety of locating tools. The evaluations focused largely on electromagnetic locaters used for metallic pipe and ground penetrating radar (GPR) which are well known in the water industry. Other technologies explored included ground penetrating radar, pulse, electromagnetic, acoustic and thermography detection. But none of these
sophisticated techniques are considered ready for the water industry and would be better managed by consultants and vendors. The conclusion well stated in the GTI report was as follows:

“Upon completing extensive research on electromagnetic locators, testing and reviewing previous testing of ground penetrating radar and investigations into alternative imaging tools it appears that electromagnetics is the most cost effective, efficient, easiest to use and fastest locating technology for roughly 80 – 90% of locates. Dry sandy areas of the country would benefit from GPR for difficult locates (namely unlocatable plastic pipe). But these units are very costly and should be thoroughly tested in a company’s operating area before purchasing.”

The UK project, “Mapping the Underworld” has been examining underground utility location methods as part of an ambitious project. The most recent (delivered in December 2012) featured a presentation on sensors by Phil Atkins of the University of Birmingham covering the work to date. The project has been developing four technologies: GPR, acoustics, low frequency electromagnetic fields (LFEMF) and passive magnetic fields. The report identifies two basic approaches to the use of GPR, “looking down” from the surface and “looking through” using a traveling sensor in the pipe. The acoustic approach appears to be innovative in its dual approach of exciting the pipe and exciting the ground to detect sound traveling along the pipe with the use of laser receiving technology. LFEMF uses tools employed by archeologists but this technique has issues with outside interference (e.g., power cables) in many locations. Passive magnetic fields appear only useful for power cables. It remains to be seen if any product will be economically viable for small systems.

The researchers identified a key source of information and potential training tools through its contact with the Infrastructure Resources, LLC. Their primary output is the monthly Damage Prevention Professional magazine and a set of training materials put out under the name of the Excavation Safety University. The magazine has any number of articles on Subsurface Utility Engineering (SUE). The organization donated a set of the training videos to the project that provided useful generic instruction on electromagnetic location of metallic pipe, wire and conduit. A WaterRF project led by Virginia Tech is generating a website called WaterID (Pipeline Infrastructure Database) to serve as a resource for the water industry through the EPA funded WERF/WaterRF partnership innovative Infrastructure Research program. The web site includes an area called Utility Engineering that provides user case studies and equipment evaluations of pipe locating equipment. The site is not yet sufficiently populated but shows promise.

Given the success of electromagnetic techniques for locating metallic pipe, the review of locating equipment sought to focus upon technologies for locating plastic and other nonmetallic pipes. Information was checked from multiple sources including well known equipment distributors, multiple web searches and updated using acquired knowledge within American Water. The leak locating devices were cross checked against a comprehensive list from the WaterRF report by the NRC, Leak Detection Methods for Plastic Water Distribution Pipes (Hunaidi et al. 1999).

In the absence of many technical summaries of techniques, contact with vendors at various exhibition halls and routine contact supplemental other searches including, of course, the internet. Some techniques were revealed and demonstrated and described in the next section of this chapter on field investigations. This includes techniques that send an acoustic (vibration) wave into the pipe, the use of ultrahigh microwave signals, a means to send a conductive wire
into a live water service line and the use of a sonde equipped acoustic camera that can be launched into the water main.

The prime non metallic pipe locating method used by many utilities (and borne out by questioning attendees at the project workshops) is divining rods, also called dowsers or witching sticks. There are very few papers written about this subject but the few papers on the topic seem to conclude that the technique has no merit. Given the extensive positive experience of operators in the water industry (including the researchers on this project), further testing and checking the science behind it is a needed area of research.

A matrix was prepared of locating equipment by vendor and type. Equipment types for pipe locating included:

- Magnetic locators – non electronic devices used to find ferrous valve boxes and manholes near the surface.
- Metal detectors – electronic devices used to find various metal, generally at relatively minimal depths
- Inductive/conductive locators - electronic devices conduct or induct an electronic signal into a metal pipe or tracer wire via the transmitter that can be found by a separate receiver.
- Split box style locators – a variation of the inductive conductive locator in which the two units are often attached by a connecting rod to induce a signal into pipe it crosses.
- Ground Penetrating Radar (GPR)/ultrasonic/infrared/microwave - GPR and ultrasonic devices bounce various radio signals that penetrate the ground and provide feedback on possible underground structures. Some systems are aided by infrared sensors which provide feedback on temperature variations as the pipe and water in it may have a different temperature than the surrounding soil (and might aid in finding leaks). Divining rods were also found and added in this section. It was interesting to see rods selling for $75.00 each (used in pairs) when a twig or bent wire can be employed.
- Pulse generating units – these devices are advertised as the method of choice for locating non-metallic pipe but range is limited. The devices induce a signal into the water than can be found acoustically several hundred feet away. Sonde insertion locators - devices that can be inserted into a pipe that can be traced above ground. These devices are generally used for sewer pipe but with proper disinfection and a depressurized line will work effectively in a water main.
- Electronic markers – a relatively new method in which markers are installed underground along the pipe (usually at key locations such as service connections and pipe bends). The markers can be activated by an above ground device that can “read” the information stored in the marker.
- Pipe travelling units – often equipped with camera units and acoustic monitoring and are discussed more fully in the next section on leak location equipment.

It is a general recommendation that some equipment at this time appears too complex or elaborate and expensive for the typical small system to consider. This would include the GPR and pipe travelling units from the list above. The use of the equipment and interpretation of information is complex and the expense of the equipment places it beyond the practical use by most small system operators. There may be instances where a vendor or consultant can provide these services for special circumstance.

In terms of specific items for locating non metallic pipe (other than GPR), the choices shown here, sonde insertion locators and pulse generating units have limitations. Assuming their
use is performed in a live service pipe, the sonde insertion locators are limited by their how far they can travel down the pipe which would in best case be the main connection. The units should have a means to be effectively disinfected before insertion into the main and NSF approval for placement of the sonde material should be provided. It is expected that these units may become more practical in the near future and will be deployed in water mains. The pulse units are limited by the limits of hearing vibration conveyed in plastic pipe. Upper limits of 250 to 300 feet are indicated as maximum range of these units.

An underappreciated alternative to locating is to use operator working knowledge of pipe layout and located surface objects (hydrants, valve boxes, curb boxes) to “connect the dots.” For example if the operator is aware that a new main was added and knows that the main started with a tapping valve that has a known distance between the tapping valve nut to the pipe that was tapped, a location of the old pipe (running perpendicular to the tap) can be established. This approach can be applied for depth as well as there are typically fix distances between the top of the valve nut and the invert of the valve (and the adjoining pipe).

Heading off future problems with newly installed nonmetallic pipe is considered part of the project. The use of tracer wire on nonmetallic mains has been documented to be effective and is practiced at many utilities including American Water. Years ago, if considered, simple wire was laid in the ground on top of the pipe. This proved problematic as the wire was easily broken or not conductive enough at depth to be detected. More recently more robust materials (like copper clad steel cable) have made the tracer wire more durable. It is now more common practice to bring the wire to the surface through valve boxes to provide a conductive trace.

More commonly practiced in the UK but not in the United States is an effective means to mark pipe or fittings with marker balls. These devices can identify key buried fittings, like service connections, tees and bends. The marker balls are placed adjacent to the site described and “programmed” to provide information about them include object description, size and age. Not only can the item be located by a corresponding tracking unit operated at ground level, the marker can be activated and provide the programmed information.

3M has developed a method to trace plastic pipe more directly. They have developed a tape and a rope type material impregnated with sensors at about six foot intervals that respond like a marker ball. A demonstration showed that a companion surface unit activated the buried markers in such a way as it imitated a conductive pipe locator with an acoustic signal that got louder as the unit passed directly over the markers. 3M is already talking to manufacturers about integrating sensors into the PVC pipe during manufacture.

**Leak Detection.** Discussion with members of the AWWA Water Loss Control Committee revealed an excellent summary report from the IWA entitled “Leak Detection Methodologies (Including ALC Decision Matrix”). This document features a decision matrix to select the appropriate leak detection method for various pipe materials and diameters. However its real value to small system operators may be found in pages clearly describing various techniques.

A list of leak detection devices was prepared in the IWA document using a matrix with vendor and product type. The types are divided into the following groups:
- **Listening Rods** – Acoustic devices designed to listen by being in direct contact with pipe or its appurtenances. Listening rods or sticks can be used by drilling at or near the pipe to listen underground and have become electronic with amplification and filtering capability. In terms of applicability for small system operators, manual listening rods are
basic and essential tools. Placing the unit on an exposed pipe, valve or hydrant can give a characteristic sound if a leak is nearby. They are commonly placed on curb or valve shutoff keys that are on the valves which also effectively transfers the leak noise. The leak survey generally employs these as technicians walk the system listening on accessible points as they travel.

- **Ground Microphones** – Acoustic devices that are designed to be placed on a surface to listen to sound below. Originally these devices were not electronic but currently most devices are electronic as they amplify and filter sound. The units can be sensitive to a listening range better than the human ear which can be displayed on a scale. Ground microphones provide a reasonably accurate location with the loudest noise commonly being found directly over the top of the break. Although there are exceptions especially when surface cover varies, this can be as reliable as more sophisticated methods like pipe correlators. Ground microphones and electronic listening rods can be packaged as they can share common parts. These devices cannot overcome some noises like heavy traffic and normal active water use.

- **Correlators** – Acoustic devices that work together to determine the presence and location of a leak. Two monitoring units placed on either side of a suspected leak location can listen simultaneously and, if the characteristics of the pipe between the units are known, a computer with correlating software can receive the signals and display the sound and calculate the leak location. A recent variation of these devices allows multiple units to be placed overnight in a larger area to find leaks. Correlators are becoming an instrument of choice as they can quickly reduce leak search time by pinpointing leaks with accuracy. Though much more expensive than microphones, they quickly prove their value in directing an experienced user in the direction and location of a leak as well as eliminate potential leak candidates.

- **Noise Loggers** – Acoustic devices that are placed at specific locations permanently to listen during the night (taking the place of the survey team approach and performing the function daily). The devices can provide some indication of whether a leak is present based on the noise it records and then can be interrogated by a passing radio receiver to download data. A variation on this technique is to move the units around from area to area (lift and shift). A more sophisticated method of employing loggers is to connect transmitters normally used for transmitting meter reads (advanced metering infrastructure, AMI) that can provide daily feedback on leaks.

- **Intrusive Acoustics** – A rough equivalent to the sondes in line locating, listening devices can be inserted into the pipe that can record both location and leak noise. Some units provide a camera or other sensors that provide condition assessment feedback. These devices also provide a means of pipe location, if needed.

This list does not include some advanced more sophisticated methods that have been employed in the industry including fiber optic cable placed inside the pipe to hear sound or placed outside the pipe (during installation) to detect changes in temperature (presumably from leaking water at variance from soil temperature). Another method known to the project team and described in both the NRC and the IWA documents is hydrogen or helium gas locating (HL5000-H2). Many of these additional systems can be quite elaborate and expensive and beyond the practical everyday use by smaller systems. Nonetheless an awareness of techniques may prove useful in genuine emergencies as vendors or consultants may propose such services for emergencies.
**Non-Revenue Water.** The research team quickly realized that it is important for any water system to have some idea of the amount of leakage that exists before embarking on a program to look for them. There are systems whose leakage is not significant or costly enough to invest in manpower and equipment to find the leakage. Conversely there are systems that may have a significant cost from lost water and can justify more expensive equipment purchases than initially thought.

There is an abundance of documents describing the water audit process. Manuals, workshop materials abound through conferences, publications and on the internet. But essentially, the backbone of the products remains the AWWA output in the form of the M36 manual and the software on the AWWA website. The M36 and the water audit materials provided by AWWA provide a fairly complete source of water loss management documentation and was a prime source for project presentation materials. However, the M36 looks at the broader water audit process and some assumptions in calculations are not designed for small systems. Additionally, the small system often needs to focus on more fundamental issues like customer metering (or lack of it) or making sure the water supply flow is accurately measured.

A number of practices in water loss management information come from the Europe via the IWA that originated many useful concepts. Tactics such as pressure management and district metering are particularly pertinent to small systems. The analysis of minimum night flow can provide the most direct confirmation on the level of leakage in small systems for several reasons.

1. Small systems are often the size of a district metered area (a DMA is typically 1000-2000 customers but can be up to 5000 customers). The small system size makes it relatively easy to estimate typical night flow in an area. It is the difference between actual flow and this estimate that provides an estimate of leak flow.
2. The small system water source is usually a single supply that can be readily metered to establish minimum night flow.
3. Small systems can be highly sensitive to seemingly small changes in water demand caused by leaks. With significant, steady leakage, the capacity of the treatment facilities and the water supply can be challenged. Operators may be readily aware of a change in the way tanks are filled or the sound of a pump.

**Task 2.2: Investigations of Field Equipment**

Field equipment investigations of various pipe and leak locating equipment have been carried out by American Water, often directly by researcher Russ Titus. Owing to a focus on plastic pipe the following equipment was investigated for pipe location: vibration induced plastic pipe location (Figure 2.1) and ground penetrating radar (GPR). Field demonstrations of line locating and leak detecting equipment at workshops served to both enliven workshops and give the researchers a firsthand inspection of some equipment in use including ground penetrating radar.

![Figure 2.1 Vibration induced PVC pipe locator connected to hydrant](image-url)
Pipe locating equipment. There are few pipe locating devices that were unfamiliar to the project team. One locating device tested, the Innspector007 (Figure 2.2) was provided by the manufacturer, SubSurface Instruments, to the research team to assess in the field. The unit, tested in March 2012, was compared to divining rods employed by an experienced NJ American employee. The Innspector007 device reportedly locates both edges of a pipe using ultra high microwave frequencies and appears simple to operate. The results were mixed as the unit appeared to find the pipe but also found other pipes and some stone on the property in close proximity, too close to differentiate one pipe from another. Finding both edges seemed to add to the confusion of analyzing so many positive signals. The operator with the divining rods had more success and found pipe without the foreknowledge of where it was located. The unit was later taken off the market.

Several companies make pulse generating pipe locators. Field testing of these acoustic devices proved what has been the major criticism of the technology that it has very limited range (250 feet). From among the manufacturers: 3M, Aquatrac, Fuji, Gutermann, Metrotech and Sewerin, the last three in this list make leak detection equipment and, as such, are thought to be the best candidates for vibration detection.

Leak locating equipment. There are some advanced devices that provide leak locating with line locating as a side benefit. The researchers witnessed a trial by Pennsylvania American Water testing a UK locating and leak detection technology marketed by Wachs Water Service. The device most appropriate for small systems (mains 12” and less), known as JD-7, can be inserted into the top of a fire hydrant. This smaller pipe size device was demonstrated at the AWWA annual conference on a hydrant in Washington, D.C. (witnessed by the project research team). PA American tested the larger counterpart, the LDS 1000 on a 24” cast iron main. The primary purpose of the test was not to locate the pipe but to look at the interior condition of the pipe, check for leaks and verify valve (open/closed) position. The larger device relies on flow in the pipe to propel the tethered unit by means of a small parachute; the JD-7 is pushed by cable. The LDS 1000 device did provide pictures but failed to travel down the pipe because of extreme tuberculation that prevented the parachute from traveling. The effort did demonstrate the potential of a camera view to examine the pipe interior. There is some concern about the focal length and clarity of pictures and cost will be an issue. But as a service for a specific problem, it is a resource worth considering for a difficult situation.

PURE Technologies offer two leak detecting units that travel inside the pipe: the Sahara leak detection method and the Smartball device. The prime features of Smartball and Sahara has been leak detection but they may be adding condition assessment features in the near future. These techniques would again be employed at this point through the vendor and not operated by the utility.

Field demonstrations at PA American Water of an Echologics leak detection product began in December 2012 so results of their product designed to improve plastic pipe results is not yet available. There is evidence that leak detection equipment has improved detection of non-metallic pipe leaks with an emphasis on lower frequency noise as suggested by the NRC prepared AWWARF report. A recent released leak locating device, PLD as manufactured by
64seconds, can be programmed to specifically track frequencies in the range associated with plastic pipe leaks and alter the infrasonic frequencies so that it is “audible to the human ear.” PA American reports improved detection of leaks on plastic service lines using a Metrotech unit. IL American Water tested correlating Gutermann leak detection units during its prototype stage with some success but the sample size is too small to evaluate. In short, the ability to detect plastic pipe leaks acoustically is improving.

Task 3: Review of Special Needs and Limits of Small System Operations

As outlined in the first chapter, small systems can have special considerations that add to the challenge of pipe location and leak detection. Obviously, most critical is limited budget to purchase sophisticated equipment. But small system users can easily calculate the potential savings of an expense of several thousand dollars by assessing the savings they would experience by digging at the leak sites on the first try or correctly identifying the location of a pipe before a third party excavator breaks it. The cost of equipment can easily offset the drain of a leak on a system with limited supply or the use of manpower and equipment spent to locate pipe and leaks.

The benefit of any equipment available to a system operator is dependent on the affordability of the equipment and the ability of the operator to find the time to learn how to use the equipment and put it to use, hopefully on a routine basis.

This project focused on the training process. As the project progressed, the research team significantly increased their reliance on feedback from small system trainers and operators to improve approaches of communication to small system users. The presentation of material at Montana State University as part of a Water Training program was followed by a larger than originally planned number of workshops in Boulder, CO; Albuquerque, NM; Bastrop, TX; Delaware, OH; Mount Laurel, NJ; and Allentown, PA. The workshops were entirely dedicated to the presentation materials and field demonstrations and no other course material.

What became clear in talking with the operators of small systems is that they frequently rely on the state rural water association for training, technical assistance and support. The parent organization Rural Community Assistance Program (RCAP) has provided some instruction on water audits and some states have equipment that can be loaned out. Future training of trainers might be best facilitated through these organizations that already have a presence in their state.

Task 4: Preparation of Presentation Materials

Original drafts of the three training modules were prepared and then passed to the research team for input and comment. Some of the early modifications included increasing the number of interactive opportunities with the audience. Interaction allowed participants to test their new knowledge and share their own experience. The PAC also viewed the materials periodically and offered suggestions. The water loss module went through the most change as it moved away from a structured water audit presentation to a more tailored presentation crafted for small systems.

The team also explored locating instruments as via demonstrations well as viewing the donated Excavation Safety University’s video series on pipe locating (with inductive/conductive equipment). These materials emphasized the value of demonstrations, provided reference materials and provided insights into effective training. It was clear that “show and tell” was an
effective means of reinforcing learning. As a result, vendors or utilities were recruited for each workshop to demonstrate equipment.

The project team held an 80 minute conference call on October 21 which featured a significant amount of discussion on communication. The Montana presentation had success in part because one presenter (Hughes) had a variety of water system experiences that he could relate to the discussion apart from the presentation materials. Sharing the experiences promoted discussion and offered the operators some comfort talking with someone who had looked for pipes and leaks. Replicating the anecdotes and experiences may be hard to replicate in some instances for some trainers and there might be increased emphasis on drawing out the experiences of operators to do this.

**Task 5: Validating the Presentation Materials**

After presentations to introduce the goals of the project at the RCAP conference, the AWWA Annual conference and a training program at Montana State University workshops were conducted at the following locations:

- November 30, 2011 at the distribution building in Boulder Colorado (Hughes and Oxenford) 35 participants
- January 31, 2012 in Albuquerque, NM at the New Mexico Environmental Finance Center (Hughes and Himmelberger) 50 participants
- February 29, 2012 at the Delaware Ohio Sewer Facility sponsored by the hosted by Ohio Rural Association (Hughes and Cannon) 40 participants
- March 21, 2012 in Bastrop, TX at the Aqua Water Supply Corporation office (Hughes and Mathis) 25 participants
- July 12, 2012 in Mount Laurel, NJ at the American Water Service office sponsored by the New Jersey Water Association (Hughes and Oppenheimer filling in for Titus). 25 participants
- August 9, 2012 in Allentown, PA at the Lehigh Valley Authority office sponsored by the Pennsylvania Rural Association (Hughes and Titus) 33 participants

It was agreed that numerous workshops provided the benefit of improving presentations and support materials and allow for some modifications as the workshops moved from the west to the east. The research team benefitted on feedback from small system trainers and operators through surveys and the reactions of vendors and other members of the team. At least two training modules were presented at each workshop. Dave Hughes was the primary instructor though Jeff Oxenford (Boulder), Russ Titus (Allentown), Heather Himmelberger (Albuquerque) and Mark Mathis (Bastrop) each handled a portion of a presentation.

Field testing of specific equipment did include demonstrations with each workshop. The water staff at Boulder, CO provided demonstration at the first workshop and the City of Albuquerque, NM water staff assisted in the second workshop. Thereafter, the workshops shifted to using vendors which is thought to be the more common practice for future workshops. This included a demonstration of more sophisticated equipment such as ground penetrating radar at Boulder and Mount Laurel workshops. In all workshops, participants had the opportunity to handle pipe locating and leak locating equipment. (Typically, hydrants were flowed slightly to simulate leaks allowing participants to hear leak-like noise.) In workshops, the field demonstration of divining rods continues to draw reaction from attendees but the success rate was evident amongst novices and supported by utilities that actively use them.
General conclusions reached during training included:

- Engaging the small operator audience to keep them involved in discussion was deemed essential to maximize their learning experience. There was an opening presentation which featured ice breakers to get the participants talking. There were opportunities for the audience to share pertinent experiences (aided by experiences of the presenters). Finally there were questions and survey type responses that required operator input.

- Guidance for small system operators should clearly assist on critical items like how to find a bad leak (confirmed by high pump output or dropping tank levels) when no water is surfacing? How to I locate buried plastic pipe? What are the best practices for assessing whether a system has leaks? Where can the operator go for assistance? Placing these as the primary feature of presentations and citing websites of technical assistance providers was identified as appropriate ways to make them available for small systems.

- Hands-on training is best for small system operators. The best feature of workshops was the demonstrations of equipment. However, due to limitations on training resources, videos could supplement hands-on training. A video was tried and seemed to be a poor use of classroom time with competent trainers on hand. It was thought better to leave as a reference to go to after training.

- Training on evaluating if water loss is an issue for individual systems was justified. The water audit is largely designed for larger systems but basic principles still applied and found useful by the small system operators. Some simple methods applicable to small systems were employed. As suggested by the AWWA manual, it is good to start somewhere and with time emphasis should be placed on the improving the quality of the data going into the water audit.

- Technical assistance providers at Rural Water or RCAP appeared essential for communicating information to small systems. The presentations should enable train the trainer features for the technical assistance providers. Providing the technical assistance providers with training resources and anecdotes of real experiences were also considered important.

- Providing references or guidance material is important for technical assistance providers and small system operators after training is provided. Information on new technologies may come from vendors going forward.
CHAPTER 3:
PRESENTATION MATERIALS

INTENT

Special needs of small users are reflected in workshop materials. Presentations featured key straightforward questions and answers. The key questions included the following:

- Should small water utilities purchase location and leak detection equipment and if so, what type of equipment?
- Can the small water utility understand and present the justification for purchasing (expensive) equipment?
- How does a small water utility determine what is an acceptable level of water loss?
- If leakage exists, Should a leak survey be done, and how often? Can it be done by the utility staff?
- Where can utilities get assistance with tools equipment and knowledge?

There was a consistent response to the question of what information we need to convey to small systems:

Provide Assistance on Knowing if a Water System Has a Problem

- Conducting a water audit was considered essential, with the fact that many small systems don’t know if they even have a problem and then deciding if it is large enough to have them commit their resources.
- In some case, identifying simple ways to determine if there is a problem is a great first step. For example monitoring storage tank levels, or comparing usage over time to see if it increases.
- Convincing the Council and Board’s the value of actively addressing water loss.
- Understanding that water loss has costs beyond just the water lost. Reducing water loss can provide energy savings, reduced chemical costs and improved revenue. Reducing water loss can also lead to saving for new infrastructure (since pipe are sized based on the volume of water used) and from consumer loss of confidence.
- A big challenge in conducting a water audit is lack of water meters, or inaccurate meters.
- Theft of water is perceived to be a large issue in small communities.
- Often finding mains is a challenge and systems lack good maps.

To address these issues the following suggestions were offered as solutions:

- Raise awareness of the importance and value of conducting a water audit.
- Develop a 10-15 minute presentation targeted to Councils and Boards.
- Provide simple steps for getting started with evaluating water loss.
- The water audit appears to be an essential first step. For example the theft of water may be an issue but how does the quantity of stolen water compare to leakage and where should the utility focus its attention?
**Provide Guidance on What to Do to Get Started**

After determining this is a problem or determining that this is something a utility should evaluate, provide guidance on:

- What type of activities should be done by the utility versus contractor services?
- Should utilities purchase location and leak detection equipment and if so, what type of equipment?
- What is an acceptable level of water loss?
- Should a leak survey be done, and how often?
- Where can utilities get assistance? Knowing that local rural water associations provide assistance to smaller system is important.

To address this it is thought a FAQ form of simple guidance for small system operators could address items like:

- What do I do if I suspect a leak?
- How do I locate buried mains?
- What are the best practices for conducting a water loss survey, acceptable level of water loss, etc.?
- Where can I go for assistance?

**Understanding the Technology and How to Use It**

- The issue for small systems isn’t so much the complexity of the technology; it is more the balance between when does the cost of purchase outweigh the benefits.
- Technical assistance providers (such as Rural Water Associations and RCAP) need information on the newer technologies. In many cases, utilities come to them as the authoritative resource. There is real value to small systems in having someone with up to date technical knowledge to call who can answer questions about technologies.
- The value of pinpointing leak locations – The less certainty about the exact leak location, the more likely the larger the excavation and the higher the cost of repair. It is necessary to understand what are the risks of not pinpointing leak locations and the consequences of digging in the wrong spot for the sake of buying less expensive equipment. The answer can vary depending on the frequency of leaks, their location and subsurface conditions.
- Some system operators will use the equipment if they have it, others may hesitate. To maximize equipment use, training is essential. Operators enjoy hands-on training much more that lecture type training.

To address this issue:

- Provide training to small system operators on how to use lower cost options for leak detection. Ensure that they understand how to use the equipment properly and the limitations of the technologies.
- Provide resources for technical assistance providers on new technologies.
• Provide training materials to technical assistance providers so that they in turn can provide training to small system operators. Field demonstrations and videos may be the best vehicles.

CONTENT

The presentation material consists of four PowerPoint slide presentations complete with notes to help assist the presenter deliver the material. Notes contain anecdotes, tips on involving the participants, and supplemental information. It is strongly recommended that the line locating and leak locating presentations be followed by a demonstration of equipment or vendor presentation, preferably immediately after the related presentation.

Introduction Presentation

The first presentation is a basic introduction to the workshop and its purpose. This presentation should be customized for the particular setting of the workshop (identifying date, location, sponsors, etc.). The primary emphasis of the orientation is to build some comfort amongst participants to engage in conversation and relate their issues and experiences. The research team made a conscious effort to recognize issues that confronted the specific location where the training was taking place. Most likely this will be less of an issue if trainers are employed from local organizations. The introduction segment also can provide the presenters with key information. Asking the group to identify the type of pipe they have, if they have customer meters, if their water supply is groundwater allows the program to be better tailored to the audience.

Pipe Location Presentation

The second presentation is a module on the subject of pipe location. It addresses why pipe location is important and how a utility can justify the cost of locating equipment. There is discussion about the value of having good maps and comment on the increasing affordability of GPS/GIS equipment. There is obvious focus on the mainstays of pipe locating, metal detection units and inductive/conductive devices, including information about the science of the technique. The locating of valve boxes and other above ground fixtures also suggests some common sense techniques for conceptualizing the pipe layout. There was little success in identifying an effective means to locate plastic or other nonmetallic pipe. Given this news, ways to install tracing systems with new pipe are provided for pipe to be installed in the future. The session closes with a discussion of possible resources for securing assistance and equipment. A suggested list of basic equipment for small system operators is provided. A set of homemade divining rods were provided at each workshop and were given away at the end of the workshop. The devices proved to be a stimulus for discussion.

Leak Evaluation Presentation

The third presentation is a training module that discusses how to gain an understanding of whether a small system has leaks. This vital interim step must take into account that some
systems have a relatively low level of leaks, a low cost for water that does leak or even a limited need to look for leaks as leaking water may surface immediately and be repaired promptly. The topic is introduced by illustrating how assessing leakage volume is important and what it can be costing the small utility. Conversation is directed not simply to the attending small system operator but presented so that the operator can also make his case to his board for securing budget to address leak issues. The third presentation then takes a modified approach to the standard Water Audit discussion. There is emphasis on definitions of non revenue water, apparent loss and real loss (leaks).

As noted previously, attendees are asked about whether their systems have meters. The short presentation on the value of accurately measuring customer water usage with meters can be skipped if all the participants have meters. Discussion then moves to the use of a master meter to record total production (or purchased) water and the typical pattern of water use that one usually sees with most systems. Emphasis shifts to the examination of minimum night flow which can be a useful and reliable indicator of leaks being present. This is especially true for small systems that tend to be residential and light commercial with very little night customer demand and absent leakage, very little night flow. Night flow monitoring for small systems is emphasized as many larger utilities tend to look at more complex approaches including 12 month rolling average of non revenue water (comparing water production and meter reads for a full year) that tend to be more time consuming and complex to analyze.

After terminology definitions are established, the water audit method of subtracting (1) metered or estimated customer consumption, estimates of (2) authorized uses and (3) unauthorized use and meter inaccuracy (apparent loss) from production to compute leakage is explained. A discussion of meter accuracy is included as many utilities wait an extended period of time to renew their meters. The leakage estimate is then converted to cost of leakage by explaining unit cost of production or purchase costs. In some small system cases, additional consideration must be given if water supply is extremely limited and leakages can threaten water supply. The module concludes with a walk through of the AWWA water audit software that reemphasizes a focus on economics.

**Leak Locating Presentation**

The fourth and final slideshow is the third training module that describes how to locate leaks. The initial focus of this module is on hidden leaks as opposed to pinpointing leaks that have come to the surface, although most equipment can be used for this purpose. It is typically that leaks that take some time to surface that is the source of most leakage and the most difficult to locate. To establish a baseline for how much to invest in leak detection (equipment and labor), a review of the economics of leakage was provided, dramatizing the unit cost of water as a major driver.

The course material refers to the M36 manual with the four cited approaches to reduce leaks and some tips on how to approach each.

- Respond quickly to known leaks and repair
- Replace pipe that is leaking in a timely way
- Reduce pressure where feasible
- Locate and repair hidden leakage

The participants are then introduced to the nature of leak vibration or noise followed by an introduction to various acoustic monitoring technologies including the more sophisticated
correlation technique. A wider of variety of leak location techniques are covered though many are very expensive and often required expert assistance. These include hydrogen gas detection, ground penetrating radar, infrared detection and traveling acoustic devices inserted into a pipe. Now grounded with types of equipment, discussion moves to strategies starting with how to employ and deploy devices.

Because of their size, small systems lend themselves to two lesser used techniques that are explained in some detail in this presentation: district metering (which refers back to night flow measurement covered in the second module) and step testing. The module concludes with a recommendation of what a small system set of instruments should contain, a suggestion to be proactive with leakage management when the economics suggest and a discussion of reference materials (including this manual) that can be used to further assist the small system user.

As a final step, it is recommended that the presenting organization request feedback from the participants. It was observed that a knowledgeable presenter who keeps the audience engaged is always the best approach.
CHAPTER 4:
REFERENCE MATERIALS

PRIMARY REFERENCES

Primary reference materials are those documents that will give small system users a solid comprehensive overview of key elements of pipe location, water loss evaluation and leak locating.

Pipe Location

The Training University Series consists of 5 videos available from excavationsafetyonline.com: Locating Best Practices, Locating Safely: Avoiding Hazards, Basic Locating Theory, Basic Locating Skills and Damage Investigation: Field Investigation Techniques. All are very good and generic with Basic Locating Skills offering the best summary of information for the small system operator. The same organization offers a free monthly magazine called Damage Prevention Professional which has articles and advertisements pertinent to line locating. An article about this project was published in the November 2011 edition.

The Water Research Foundation report, Underground Facility Pinpointing by the Gas Technology Institute (Farag and Vetter, 2011) confirms the use of electromagnetic locators and discusses GPR and the use of GPS and discusses various vendors involved in the technologies.

Water Loss Evaluation

The AWWA M36 Manual (AWWA, 2009) and companion Water Audit software tool on the AWWA website is currently the state of the art in the industry. Small system operators are directed to pages specifically tailored to small systems.

The publication Water Loss Control (Thornton et al, 2008) provides an extensive and highly technical presentation on the most topics of water loss. Notable descriptions include night flow analysis and district metering, step testing and how to organize a water loss program.

Water Use Auditing: a guide to accurately measure water use and water loss is a document available on the internet from the New Mexico Rural Water Association. That provides a simplified approach for the small system user.

Leak Locating

The International Water Association (IWA) has a document available on the internet entitled Leak Location and Repair (Water Loss Task Force, 2007) that contains a comprehensive look at leak monitoring and detection strategies as well as locating techniques. An updated version of the content should be made available in an upcoming document on Leak Detection Methodologies which is now in draft form.

The Water Research Foundation report, Leak Detection Methods for Plastic Pipe (Hunaidi et al, 1999), describes the technical nature of vibration of plastic pipe and provides a summary of leak detection devices of the time. An updated list is provided in the Appendix.
Rural Water Associations

One of the best resources for small systems is the state and national rural water associations. The National Rural Water Association has on its website its Water University which has courses. Presently, there is a one hour course (fee) for Water Reductions Strategies and Best Practices. There are far more services available at the state level, too many to list here. Training classes are frequently held at the state level on leak detection and line locating tools. Some state rural associations offer services have circuit riders that can provide on-site technical assistance. These services may include mapping services, line locating and leak detection services as well as making equipment and related training available.

VIDEO REFERENCES

A new and emerging opportunity for small system operators will be videos of the techniques in use. Many are available on You Tube often developed and sponsored by equipment vendors. Table 4.1 includes links to a sampling of these videos. The listings here in no way should be considered an endorsement of the explicit directions or the products. They do, however, provide a good example of the type information available. Matching the applicable videos to equipment purchased can prove useful though direct vendor training is preferred. Links to all these videos can be found in the reference section.

<table>
<thead>
<tr>
<th>Video</th>
<th>Description</th>
<th>Web link</th>
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<tr>
<td>Metrotech 9800DLXT Line Locator Training</td>
<td>3 Part You Tube Videos on line locating</td>
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<td>Vivax-Metrotech vLocML Line &amp; Marker Locator</td>
<td>Discusses the marker ball technology</td>
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<td>Schonstedt (10 modules)</td>
<td>Takes the viewer step by step through locating</td>
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<td>AMProbe AT5000 Outdoor Demo</td>
<td>Shows components</td>
<td><a href="http://www.youtube.com/watch?v=unctpk1w5cu">http://www.youtube.com/watch?v=unctpk1w5cu</a></td>
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<tr>
<td>Fisher TW-5</td>
<td>Covers the split box method</td>
<td><a href="http://www.youtube.com/watch?v=lmm3qryw0y">http://www.youtube.com/watch?v=lmm3qryw0y</a></td>
</tr>
<tr>
<td>Goldak TR5 Pipe and Cable Locator Demo</td>
<td>Line location video</td>
<td><a href="http://www.youtube.com/watch?v=0tnohpz2u2k">http://www.youtube.com/watch?v=0tnohpz2u2k</a></td>
</tr>
<tr>
<td>3M Dynatel 573</td>
<td>Several videos available</td>
<td><a href="http://www.youtube.com/watch?v=se2ojxtnnr8">http://www.youtube.com/watch?v=se2ojxtnnr8</a></td>
</tr>
<tr>
<td>Pipehorn Model 100 Pipe And Cable Locator</td>
<td>Demonstration</td>
<td><a href="http://www.youtube.com/watch?v=4ponglnxsjm">http://www.youtube.com/watch?v=4ponglnxsjm</a></td>
</tr>
</tbody>
</table>

(continued)

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### Table 4.1 (Continued)

<table>
<thead>
<tr>
<th>Video</th>
<th>Description</th>
<th>Web link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rycom 8850 Pathfinder II Pipe And Cable Locator</td>
<td>Pie locating video</td>
<td><a href="http://www.youtube.com/watch?v=jaqchkulvoq">http://www.youtube.com/watch?v=jaqchkulvoq</a></td>
</tr>
<tr>
<td>Ashtech Mobile Mapper10 GIS</td>
<td>Product Overview</td>
<td><a href="http://www.youtube.com/watch?v=th9qfwtb2di">http://www.youtube.com/watch?v=th9qfwtb2di</a></td>
</tr>
<tr>
<td>Divining Rod Video</td>
<td>Find underground pipes easily – rod construction from coat hanger and how they are employed</td>
<td><a href="http://www.youtube.com/watch?v=zgap9ujpawg">http://www.youtube.com/watch?v=zgap9ujpawg</a></td>
</tr>
<tr>
<td>Echologics: Making The Smart Move In New Orleans, La</td>
<td>Explains key components of leak noise correlators</td>
<td><a href="http://www.youtube.com/watch?v=vyx8zg1zora">http://www.youtube.com/watch?v=vyx8zg1zora</a></td>
</tr>
<tr>
<td>Gutermann Aquascope3 training video Gutermann has companion videos covering ground microphones and listening sticks</td>
<td>A lengthy video but provides a significant amount of information about leak noise in the first ten minutes before becoming vendor specific. There are some good audio captures of different leak sounds from different leaks.</td>
<td><a href="http://www.youtube.com/watch?v=lvrfno6m62g">http://www.youtube.com/watch?v=lvrfno6m62g</a></td>
</tr>
<tr>
<td>Tricorr Touch Leak Correlator</td>
<td>Vendor specific but contains the basics common to leak noise correlators.</td>
<td><a href="http://www.youtube.com/watch?v=qsq5w_hctag">http://www.youtube.com/watch?v=qsq5w_hctag</a></td>
</tr>
</tbody>
</table>
CHAPTER 5:
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The primary output of this project is the appended presentation material that offers the needed technical information on pipe locating and leak detection in an involving manner for participants in a workshop setting. The workshop material contains information related to the individual slides with further guidance, taps and anecdotes to help the trainer present the material. A high priority is placed on involving participants by sharing problems and their own opinions and experiences. The workshop is greatly aided by live demonstrations of locating equipment.

In addition to providing material about leak detection, it is essential that the utility have some sense of their leakage and other non revenue water losses to know when to look for leaks and have an idea of what the cost of the leakage can be. Consequently there is a third module on determining water loss in addition to modules on line locating and leak detection.

An emphasis was placed on identifying techniques for locating plastic and other non-metallic pipe and leaks on these pipes. Although there are superior simple products for finding metallic pipe and leaks on metallic pipe, the same cannot be said for non-metallic pipe. Pipe locating methods are limited and it has only been recently that some improvement in detecting plastic pipe leaks is increasing in range. The use of divining rods is a common method still in use to find nonmetallic pipe, regardless of some who question its viability.

RECOMMENDATIONS

It is recommended that this material be made available to AWWA and groups who reach out to small system operators. Consideration should be given to the process known as “train the trainer” to assist those making presentations that may not be totally familiar with the presentation content.

It is essential that presentations be supplemented by vendor or consultant demonstrations of equipment. As long as the commercial aspects of demonstrations are held in check, this is an effective compliment to the material provided.

It is recommended that work continue on exploring methods to locate buried pipe and undetected leaks on nonmetallic materials. While there is some improvement, there remains considerable difference in detection between metallic and nonmetallic pipe. There are some indications that improvements are being made in locating leaks on plastic pipe. Small system users with plastic pipe should examine a number of leak locating devices to test their ability to detect such leaks.

It is recommended that the Water Research Foundation consider a project to more carefully evaluate the use of divining rods. Numerous utilities and the research team have found that the units work for them though the science and the evidence of their functionality is refuted. There is a reason why many utilities use these simple devices with some level of success. The researchers did not identify a non-invasive technique to be more effective on non-metallic pipe.

Finally, the researchers would urge small system operators (and all operators) to place durable tracer wire or marker balls along non-metallic pipes that they are currently installing.
Effective proactive marking combining with good mapping will be the most effective way to extend the location problem beyond pipes that are already in the ground. The plastic pipe industry should make a better effort to encourage the use of tracer wire and other buried markers in their standards and published materials.
**APPENDIX**

**WORKSHOP EVALUATION SUMMARIES**

**Survey Totals**

<table>
<thead>
<tr>
<th>Question 1: Overall I rate this workshop</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>++</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>+</td>
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<table>
<thead>
<tr>
<th>Question 2 - Main reason why I attended</th>
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<tbody>
<tr>
<td>To learn about something new</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To build new skills</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To solve a practical problem</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To gain a knowledge of resources</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To meet others working in my area</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Other (specify)</td>
<td>5</td>
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3. Did the workshop meet your expectations?

<table>
<thead>
<tr>
<th>Fully</th>
<th>Partially</th>
<th>Not at all</th>
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<tbody>
<tr>
<td>71</td>
<td>28</td>
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4. In this workshop the content of the presentations were:

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</thead>
<tbody>
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<td>46</td>
<td>34</td>
<td>2</td>
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5. The organization of the workshop was:

<table>
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</tr>
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<td>67</td>
<td>30</td>
<td>1</td>
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</table>

6. The instructor pace/delivery was:

<table>
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<th>--</th>
</tr>
</thead>
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<td>70</td>
<td>25</td>
<td>3</td>
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</table>

7. The opportunity for group involvement was:

<table>
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<th>0</th>
<th>-</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Examples of Responses to Open Ended Questions

8: What did you like most about the workshop?
Hands-on activities and demonstrations
Good practical information
Knowledgeable instructors, shared knowledge and field work
Vendor info
The networking
To discover that everyone has loss!
Information concerning new equipment

9. What did you like least about the workshop?
Lack of time or workshop took too long (about evenly split)
Water audit (exercise, software tool ...)

10. What did you learn that you will be able to use on the job next month?
AWWA water audit online
Inexpensive ways to locate pipe leaks
Verified that the tools already available are still valid
Finding leaks by sonic or RF devices
Resources, where to go for information
I learned basic use of a line locator
Beginning to incorporate GPS into our map system
How to properly use leak detecting equipment
Need for metering, percentage of water lost due to unavailable leaks
Gathered info for supervisors to consider re: water loss and leak detection
Pressure control

11. Any suggestions for improving this workshop?
More hands on
Improve the exercise on the water audit tool. Laptops with hands-on would be good
More direction for group exercises
Bigger slides in work book
More demonstrations of available equipment
# TABLES OF LOCATING DEVICES

## Pipe and Appurtenance Locating Equipment

### Magnetic Locators and Metal Detectors

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua Magnetic</td>
<td>Aqua curb and valve box locator (non electronic)</td>
</tr>
<tr>
<td>DML</td>
<td>DML 2000M Magnetic Locator</td>
</tr>
<tr>
<td>Fisher</td>
<td>FP-ID 2100 and FX-3 Magnetic Locator</td>
</tr>
<tr>
<td>Goldak</td>
<td>7200 Valve Locator, 720 Valve Locator</td>
</tr>
<tr>
<td>Heath</td>
<td>Magna Lock</td>
</tr>
<tr>
<td>Magna Trak</td>
<td>100, 101, 102, 200,202 Locators</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>VM880 Ferromagnetic Locator</td>
</tr>
<tr>
<td>Pipehorn</td>
<td>Maghorn MD-450,</td>
</tr>
<tr>
<td>Prototek</td>
<td>FR-1</td>
</tr>
<tr>
<td>RadioDetection</td>
<td>RD312</td>
</tr>
<tr>
<td>Rycom</td>
<td>Magnastick MSL</td>
</tr>
<tr>
<td>Schonstedt</td>
<td>MA51BX Locator Tracer, GA52CX,GA72CD,GA92XT</td>
</tr>
<tr>
<td>Sewerin</td>
<td>M130, Ferrotec</td>
</tr>
<tr>
<td>SubSurface</td>
<td>ML-1 Ferromagnetic Locator</td>
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</tbody>
</table>

### Inductive Conductive Units/independent Transmitter and Receiver

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M (Dynatel)</td>
<td>Dynatel 2220M Series P/C Locators (2250, 2550)</td>
</tr>
<tr>
<td>Amprobe</td>
<td>AT3500, AT5000</td>
</tr>
<tr>
<td>Armada</td>
<td>PRO-871C I38 Pipe and Cable Locator</td>
</tr>
<tr>
<td>Ditch Witch</td>
<td>Subsite RT-150 Locator, RT-250, RT-830 I25RT-950 Pipe &amp; Cable Locators</td>
</tr>
<tr>
<td>Fisher</td>
<td>TW-6 Locator, TW-82 Digital Line Tracer, TW7700, TW8800 Line Tracers</td>
</tr>
<tr>
<td>Fuji</td>
<td>PL-960, PL-2000</td>
</tr>
<tr>
<td>General Pipe Cleaners</td>
<td>GenEye Digital</td>
</tr>
<tr>
<td>Goldak</td>
<td>Triad 2310, 5600 SI</td>
</tr>
<tr>
<td>Greenlee (Textron)</td>
<td>Greenlee Model 501 Tracker II Cable and Pipe Locator</td>
</tr>
<tr>
<td>Heath</td>
<td>Sure Lock Locator, (HCTx Transmitter), Sure lock All Pro, Sure Lock Utility Pro</td>
</tr>
<tr>
<td>Jameson</td>
<td>17-300R Utility Locator</td>
</tr>
<tr>
<td>McLaughlin</td>
<td>Verifier G2 Digital Locator</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>810 RF Line Tracer, 810 DX Line Tracer, 850 RF Line Tracer, 9860 XT Dual Frequency Locator, 9890 XT Dual Frequency Locator, VM 550, VM560, VLoc 9800</td>
</tr>
<tr>
<td>Pipehorn</td>
<td>Pipehorn 800 series Locators</td>
</tr>
<tr>
<td>Prototek</td>
<td>LF2000, LF2200</td>
</tr>
<tr>
<td>RadioDetection</td>
<td>RD5000, RD7000, RD8000</td>
</tr>
<tr>
<td>Ridgid</td>
<td>NavTrack II, NavTrack Scout Receiver, SeekTech SR20 and SR60 P&amp;C Locators</td>
</tr>
<tr>
<td>Rycom</td>
<td>8879 (high output), 8873 Pathfinder (dual frequency), 8869 Locator (multi frequency).</td>
</tr>
<tr>
<td>Schonstedt</td>
<td>Tracemaster II, XTpc Pipe &amp; Cable Locator</td>
</tr>
<tr>
<td>Sewerin</td>
<td>Utilitrac</td>
</tr>
<tr>
<td>Subsite</td>
<td>830 R/T, 950 R/T, 970T Pipe &amp; Cable Locator</td>
</tr>
<tr>
<td>SubSurface</td>
<td>PL-920 Audio Frequency Locator, PL-1500 P&amp;C Locator, PL2000 P&amp;C Locator</td>
</tr>
</tbody>
</table>
### Inductive Conductive Units/Split Box Type

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model/Description</th>
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<tbody>
<tr>
<td>Detectron</td>
<td>505 Go fer P&amp;C Locator</td>
</tr>
<tr>
<td>Fisher</td>
<td>TW-6 Pipe &amp; Cable Locator</td>
</tr>
<tr>
<td>Goldak</td>
<td>902 Split Box, 902 Scanner</td>
</tr>
<tr>
<td>Heath</td>
<td>Split Lock</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>480B RF Pipe &amp; Cable Locator</td>
</tr>
</tbody>
</table>

### Plastic Pipe Locators

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model/Description</th>
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</thead>
<tbody>
<tr>
<td>AquaTrac</td>
<td>AquaTrac P50 and P 100 PVC Pipe Locators</td>
</tr>
<tr>
<td>Fuji</td>
<td>NPL-100</td>
</tr>
<tr>
<td>Gutermann</td>
<td>Detecton</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>RSP-3 Plastic Pipe Locator</td>
</tr>
<tr>
<td>Pipetool</td>
<td>P50 Plastic Water Pipe Locator</td>
</tr>
<tr>
<td>Sewerin</td>
<td>Com bifon</td>
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</table>

### Marker Ball Technologies

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M (Dynatel)</td>
<td>ScotchMark Marker balls, 3M EMS ID Marker Locator 1420</td>
</tr>
<tr>
<td>Ditch Witch</td>
<td>950R/T</td>
</tr>
<tr>
<td>Fuji</td>
<td>MLH-1</td>
</tr>
<tr>
<td>Greenlee (Textron)</td>
<td>Marker Mate Marker Locator</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>760DX Marker Locator</td>
</tr>
<tr>
<td>Rycom</td>
<td>8890 Marker Ball Locator</td>
</tr>
<tr>
<td>Subsite</td>
<td>950REmL Marker Ball locating system</td>
</tr>
<tr>
<td>Telemark</td>
<td>Diskmark</td>
</tr>
<tr>
<td>Tempo</td>
<td>OMNI marker M160-OM165, Unimarker</td>
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</table>

### Sonde Technology

<table>
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<tr>
<th>Brand</th>
<th>Model/Description</th>
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<tbody>
<tr>
<td>Ditch Witch</td>
<td>Subsite 752 TRK with 86 Beacon Sondes</td>
</tr>
<tr>
<td>Goldak</td>
<td>Triad 2310, 5600 SI, (with sondes)</td>
</tr>
<tr>
<td>Jameson</td>
<td>Water Line Tracer (Traceable Rodder)</td>
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<tr>
<td>Metrotech (Vivax)</td>
<td>Flexisonde</td>
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<tr>
<td>RadioDetection</td>
<td>RD7000, RD8000</td>
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<tr>
<td>Ridgid</td>
<td>NavTrack Scout Receiver</td>
</tr>
<tr>
<td>Rycom</td>
<td>Rycom Sonde</td>
</tr>
<tr>
<td>Schonstedt</td>
<td>XTPc82, PCS 800</td>
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</table>
## Leak Detection Equipment

### Listening Sticks (identified only if sold separately)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model/Description</th>
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<tr>
<td>3M (Dynatel)</td>
<td>LS-20LS-10 Listening stick</td>
</tr>
<tr>
<td>Echologics</td>
<td>Leak listener</td>
</tr>
<tr>
<td>FCS/Palmer</td>
<td>S20 (non electronic), Lmic, S30 Surveyor</td>
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<tr>
<td>Fuji</td>
<td>LS1.0 (non electronic), FSB-8D,</td>
</tr>
<tr>
<td>Guttermann</td>
<td>Aquascop 3 listening stick, Pocket ground microphone</td>
</tr>
<tr>
<td>Itron</td>
<td>Digital leak detector</td>
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<tr>
<td>Metrotech (Vivax)</td>
<td>HL 10, PAM hydro (water contact)</td>
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<tr>
<td>Primayer (UK)</td>
<td>Hykron</td>
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<tr>
<td>RadioDetection (SPX)</td>
<td>RD542, RD546</td>
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<tr>
<td>Sewerin</td>
<td>Aquatertest</td>
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<tr>
<td>SubSurface</td>
<td>LD-8</td>
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### Ground Microphones

(These units may include a listening stick in combination)

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<td>3M (Dynatel)</td>
<td>Electro-acoustic leak detector</td>
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<tr>
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<td>Waterpoint PLD</td>
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<tr>
<td>Detectron</td>
<td>XL-2</td>
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<tr>
<td>Echologics</td>
<td>Leaktuner</td>
</tr>
<tr>
<td>FCS/Palmer</td>
<td>Xmic ground mic</td>
</tr>
<tr>
<td>Fisher</td>
<td>XLT-17, XLT-30 Leak detector</td>
</tr>
<tr>
<td>Fuji</td>
<td>LD-7 DNR 18, HG-10All</td>
</tr>
<tr>
<td>Goldak</td>
<td>777A, 777B, NE 77, Model 4360</td>
</tr>
<tr>
<td>Gutterman</td>
<td>Aquascop 3 ground microphone, Aquascop 550</td>
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<tr>
<td>Heath</td>
<td>Geophone (nonelectronic), AQUA-SCOPE</td>
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<tr>
<td>Itron</td>
<td>Digital Leak Detector</td>
</tr>
<tr>
<td>Metrotech (Vivax)</td>
<td>HL 5000</td>
</tr>
<tr>
<td>Primayer (UK)</td>
<td>Mikron</td>
</tr>
<tr>
<td>RadioDetection (SPX)</td>
<td>RD545</td>
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<tr>
<td>Sewerin</td>
<td>Aquaphon T-10</td>
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<tr>
<td>SubSurface</td>
<td>LD-7 LD-12, LD-15, LD-18</td>
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### Leak Noise Correlators

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<th>Manufacturer</th>
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<tr>
<td>3M (Dynatel)</td>
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<tr>
<td>Casella Spectrascan</td>
<td>Aquacorr</td>
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<tr>
<td>Echologics</td>
<td>LeakFinder RT, LeakFinder RT Mini,</td>
</tr>
<tr>
<td>FCS/Palmer</td>
<td>TriCorr Touch, AccuCorr DX, AC Digital, Digicall</td>
</tr>
<tr>
<td>Fuji</td>
<td>LC-2500</td>
</tr>
<tr>
<td>Gutterman</td>
<td>PAL300, Aquascan610, 610L AquascanTM trunk main)</td>
</tr>
<tr>
<td>Itron</td>
<td>DigiCorr, Zcorr</td>
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<tr>
<td>Metrotech (Vivax)</td>
<td>HL 6000X</td>
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<tr>
<td>Primayer (UK)</td>
<td>Eureka2R, Eureka Digital, Enigma-hyQ</td>
</tr>
<tr>
<td>RadioDetection (SPX)</td>
<td>RD533</td>
</tr>
<tr>
<td>Sewerin</td>
<td>SeCorr 300, SeCorr 08, Stethophon 06</td>
</tr>
<tr>
<td>SubSurface</td>
<td>LC2500</td>
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</tbody>
</table>
### Transmitting or Datalogging Acoustic Monitors

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
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<tbody>
<tr>
<td>3M (Dynatel)</td>
<td>Noise Master Logger LS-45</td>
</tr>
<tr>
<td>FCS/Palmer</td>
<td>Permalogs</td>
</tr>
<tr>
<td>Gutermann</td>
<td>Zonescan</td>
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<tr>
<td>Itron</td>
<td>SaveSource</td>
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<tr>
<td>Metrotech (Vivax)</td>
<td>HL 7000, Leak Spy</td>
</tr>
<tr>
<td>Primayer (UK)</td>
<td>phocus2</td>
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<tr>
<td>RadioDetection (SPX)</td>
<td>RD521</td>
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<tr>
<td>Sewerin</td>
<td>SePem 01, SePem 01 GSM</td>
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### Gas (hydrogen/helium) Locators

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
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<tbody>
<tr>
<td>Inficon</td>
<td>ISH2000C</td>
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<tr>
<td>Metrotech (Vivax)</td>
<td>HL5000-H2</td>
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<tr>
<td>Radiodetection</td>
<td>RD560</td>
</tr>
<tr>
<td>Sewerin</td>
<td>Variotec 460</td>
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### Insertable Cameras and Other

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Entech Engineering</td>
<td>GPR and infrared (truck and helicopter options)</td>
</tr>
<tr>
<td>Pure</td>
<td>Sahara (leak detection and camera)</td>
</tr>
<tr>
<td>Wachs</td>
<td>JD7 (leak detection and camera)</td>
</tr>
</tbody>
</table>
REFERENCES

LITERATURE


AWWA Free Audit Software, website


New Mexico Environmental Finance Center, Phase III Report, Head to head Evaluation Active versus Passive Leak Detection Methods, July 2007 (prepared for Albuquerque Bernalillo County).


WEBSITE REFERENCES

Vendor Equipment

3M (Dynatel)  http://solutions.3m.com/wps/portal/3M/en_US/Telecom/Home/Products/LocatingMarking/
3M (Dynatel)  http://solutions.3m.com/wps/portal/3M/en_WW/Track_Trace/home/Products/product_catalog/?PC_7_RJH9U52300MUA0I8QRDF60GTT000000_nid=D8NP053G8Mbe8ZB2282GCH9g
64 seconds  http://www.sixtyfourseconds.com/features.html
Amprobe  http://www.amprobe.com/Amprobe/usen/Products/Wire-Tracers.htm
Aqua Magnetic  http://www.aqualocator.com/
AquaTrac  http://www.mswinteractiveedesigns.com/staging/heitman/pipeline-locating-system.asp
Armada  http://armadatech.com/industry/irrigation
Ditch Witch  http://www.ditchwitch.com/utility-locators/
DML  http://www.magneticlocator.com/
Echologics  http://echologics.com/products/
Entech Engineering  http://www.entechnworld.com/markets/water_and_sewer
Fuji  http://www.fujitecom.com/
General Pipe Cleaners  http://www.drainbrain.com/genea/index.html
Goldak  http://www.goldak.com/
Greenlee (Textron)  http://www.greenlee.com/products/LOCATOR%2540dBURIED-LINE.htm?product_id=18382
Gutermann  http://en.gutermann-water.com/products/
Heath  http://www.heathus.com/_hc/index.cfm/products/water
Itron  https://www.itron.com/na/productsAndServices/water/Pages/data-collection.aspx
McLaughlin  http://www.mightymole.com/index.php?option=com_content&view=article&id=68&Itemid=84
Metrotech (Vivax)  http://www.vivax-metrotech.com/
OMNI (Tempo)  http://instecorp/tempo/tempo_omni.html
Pipehorn  http://www.wedetectors.com/Uni%20Marker%20Electronic%20Marker%20We.htm
Primayer (UK)  http://www.primayer.co.uk/wlc.htm
Prototek  http://www.prototek.net/
Radiodetection (SPX)  http://www.radiodetection.com/menu_map_level_2.asp?sec_id=2689
Rycom  http://www.rycominstruments.com/Products.html
Schoenstedt  http://www.schoenstedt.com/index.cfm?page=industry_water_and_sewer_pipeline
SubSurface  http://www.subsurfaceleak.com/
Wachs  http://www.wachsresource.com/services/pipeline-management/investigator

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Instruction References

The following videos were referenced as supplemental videos to help small system users understand some equipment basics. These do come from vendors but were selected because the documentation provides underlying principles and their equipment are similar to others.

Pipe Locating

Metrotech 9800DLXT Line Locator Training (3 Part You Tube Videos)  
http://www.youtube.com/watch?v=nua4njkiouc

vivax-metrotech vlocml line & marker locator  
http://www.youtube.com/watch?v=nblqy6he4mc

schonstedt locating  
http://www.youtube.com/watch?v=u9r4t7mwpsm

amprobe at5000 outdoor demo  
http://www.youtube.com/watch?v=unctpk1w5cu

fisher tw-5 split box  
http://www.youtube.com/watch?v=lm3qrywooy

goldak tr5 pipe and cable locator demo  
http://www.youtube.com/watch?v=0tnohpz2u2k

3m dynatel 573a cable locator  
http://www.youtube.com/watch?v=sc2ojxtnrr8pipehorn model 100 pipe and cable locator demonstration

ridgid navitrack underground line locator  
http://www.youtube.com/watch?v=3sbunwbzyum

rycom 8850 pathfinder ii pipe and cable locator  
http://www.youtube.com/watch?v=jaqchulvoq

GIS/GPS Mapping

Ashtech Mobile Mapper 6 GIS  
http://www.youtube.com/watch?v=Th9QFwTB2dI

Dowsing Rods

Divining Rod Video – Find underground pipes easily –  
http://www.youtube.com/watch?v=zGap9uJPawg
Leak Detection

Gutermann Aquascope3 Training
http://www.youtube.com/watch?v=LvrfNo6m62g

Tricorr Touch Leak Correlator
http://www.youtube.com/watch?v=QsQ5W_hCTAg
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M</td>
<td>Minnesota Mining and Manufacturing (company)</td>
</tr>
<tr>
<td>AWSC</td>
<td>Aqua water Supply Corporation</td>
</tr>
<tr>
<td>AWWA</td>
<td>American Water Works Association</td>
</tr>
<tr>
<td>CD</td>
<td>compact disk</td>
</tr>
<tr>
<td>DMA</td>
<td>district metered area</td>
</tr>
<tr>
<td>DSS</td>
<td>distribution System Symposium</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>FAQ</td>
<td>frequently asked questions</td>
</tr>
<tr>
<td>GIS</td>
<td>geographical information system</td>
</tr>
<tr>
<td>GPR</td>
<td>ground penetrating radar</td>
</tr>
<tr>
<td>GPS</td>
<td>ground positioning system</td>
</tr>
<tr>
<td>GTI</td>
<td>Gas Technology Institute</td>
</tr>
<tr>
<td>HZ</td>
<td>hertz</td>
</tr>
<tr>
<td>IWA</td>
<td>International Water Association</td>
</tr>
<tr>
<td>LFEMF</td>
<td>low frequency electromagnetic fields</td>
</tr>
<tr>
<td>LLC</td>
<td>limited liability corporation</td>
</tr>
<tr>
<td>M36</td>
<td>Manual 36 (AWWA Water Loss)</td>
</tr>
<tr>
<td>M55</td>
<td>Manual 55 (AWWA Polyethylene Pipe)</td>
</tr>
<tr>
<td>NRC</td>
<td>National Research Council (of Canada)</td>
</tr>
<tr>
<td>NSF</td>
<td>National Standards Foundation</td>
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<tr>
<td>PAC</td>
<td>Project Advisory Committee</td>
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<tr>
<td>PE</td>
<td>Polyethylene</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<tr>
<td>RCAP</td>
<td>Rural Community Association Partnership</td>
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<tr>
<td>RF</td>
<td>radio frequency</td>
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<td>SUE</td>
<td>subsurface utility engineering</td>
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<td>United Kingdom</td>
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<tr>
<td>WATERID</td>
<td>Water Infrastructure Database</td>
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<tr>
<td>WRF</td>
<td>Water Research Foundation</td>
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<tr>
<td>WERF</td>
<td>Water Environment Research Foundation</td>
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