American Water Works Association

Dedicated to the World's Most Important Resource®

CONTROLLING NON-REVENUE WATER IN DRINKING WATER UTILITIES

COURSE 3

EFFECTIVE LEAKAGE AND PRESSURE MANAGEMENT

ACKNOWLEDGMENTS

Project Contractor

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COURSE LEARNING OBJECTIVES

As a result of this course, you will be able to:

Explain	how leakage occurs in water distribution systems and the problems leakage causes
Describe	how leakage imparts direct and indirect costs on water utility operations
Define	proactive leakage management and mitigation measures
Identify	the ways to detect leaks and pinpoint them
Assess	your system's pressure levels and potential for improved leakage management
Determine	the most appropriate and cost-effective actions to monitor and control leakage in your system

Course 3
Effective Leakage and Pressure Management

Course Agenda

Module Number	
1	How leakage occurs and what it costs water utilities
2	Proactive Leakage Management
3	Pressure Management Benefits and Applications
4	Keeping your leakage control efforts going
	Course Summary

MODULE 1

Leakage Occurrences and Costs

Module 1
How Leakage Occurs and What it Costs Water Utilities
Agenda

A. Defining the types of leakage

B. The Life of a Leak

C. The direct and indirect costs of leakage

Module 1 Learning Objectives

As a result of this module participants should be able to:

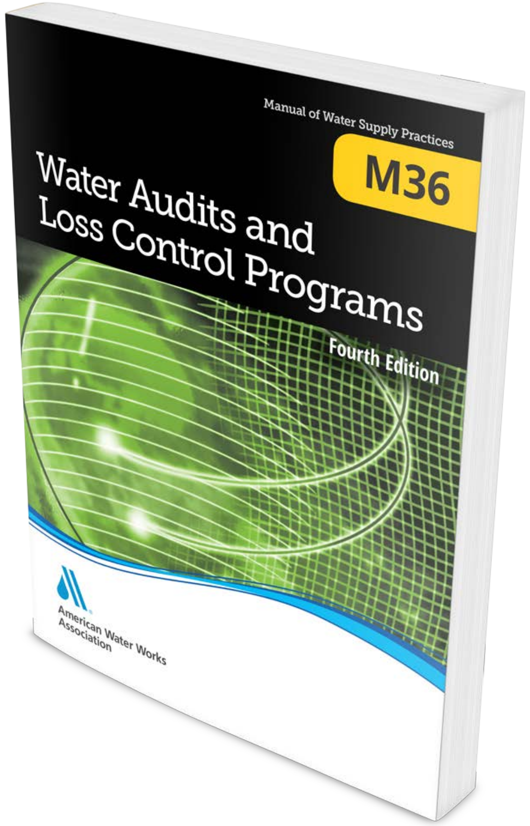
1. Identify the ways that leakage occurs and define the types of leakage
2. Analyze the volumes lost to leakage as a function of leak run time
3. Calculate the cost impacts of leakage

A. Defining the Types of Leakage

The AWWA M36 Manual:

Water Audits and Loss Control Programs

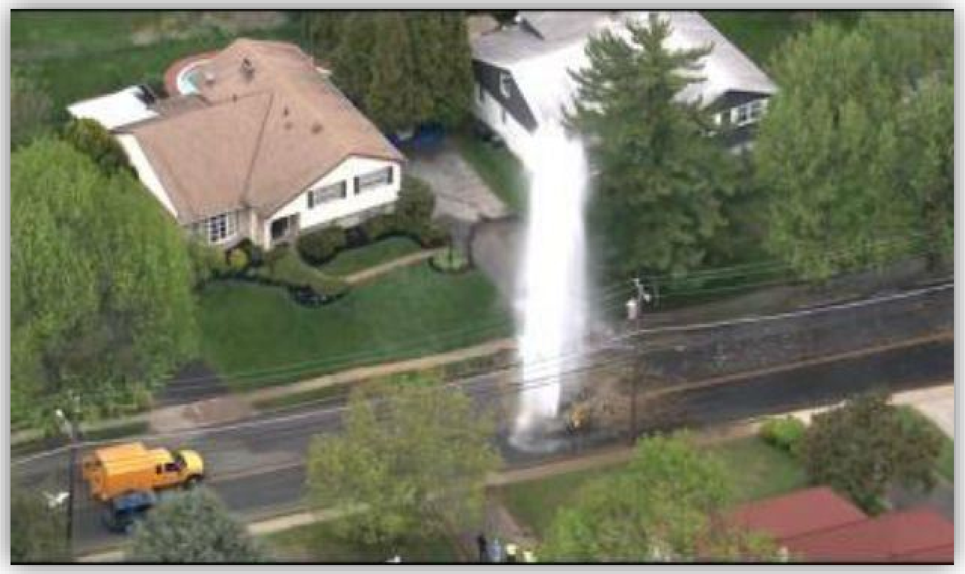
covers it all!



AWWA's M36 Manual provides detailed guidance on leakage and pressure management technologies

A. Defining the Types of Leakage – LEAKAGE FACTS

1. Leaks occur due to stresses in the environment that exceed the structural capacity of the piping.
2. All water systems have leaks! Only the number and rate of leakage varies.
3. Leaks come in all sizes.



Major water main break under high pressure

Customer service line leak

A. Defining the Types of Leakage

Causes of Leakage	Causes of Leakage
• Inferior or defective pipe materials • Poor workmanship or materials handling • Operational errors: pressure spikes • Corrosion of metallic pipe • Seasonally induced stresses: cold winters or hot summers	• Poor quality of leak repair work • Accidental or deliberate damage • Added stress from heavy truck traffic on older pipe that was not designed for the heavy loading

A. Defining the Types of Leakage

The annual leakage volume and cost from the AWWA Water Audit

- The AWWA Free Water Audit Software calculates the annual volume of real (leakage) losses
- The Software also calculates the costs of leakage

	Volume MG/Yr	Value $/Yr
Apparent Losses	296.7	$1,210,051
Real Losses	1,537.2	$801,241
Unbilled Authorized Cons	75.8	$39,494
Non-Revenue Water	1,909.6	$2,050,786

AWWA Free Water Audit Software Dashboard worksheet excerpt

	WATER LOSSES				1,833.825	MG/Yr
	Apparent Losses					
	Default option selected for Systematic Data Handling Errors, with automatic data grading of 3					
SDHE	Systematic Data Handling Errors:	n	g	3	19.483	MG/Yr
CMI	Customer Metering Inaccuracies:	n	g	4	257.705	MG/Yr
UC	Unauthorized Consumption:	n	g	3	19.483	MG/Yr
	Default option selected for Unauthorized Consumption, with automatic data grading of 3					
	Apparent Losses:				296.671	MG/Yr
	Real Losses					
	Real Losses:				1,537.154	MG/Yr
	WATER LOSSES:				1,833.825	MG/Yr
	NON-REVENUE WATER					
	NON-REVENUE WATER:				1,909.592	MG/Yr

AWWA Free Water Audit Software Worksheet excerpt

A. Defining the Types of Leakage – KNOWLEDGE CHECK

An operator claims to have no leakage in their water distribution system.

Is this statement True or False?

TRUE

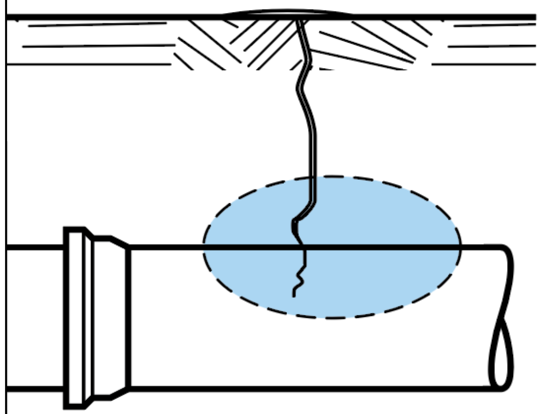
FALSE

A. Defining the Types of Leakage

The three types of leakage

I. Reported Leakage

- Water from **visible** leaks or breaks
- Often (but not always) high flow events
- Because it is visible, it is usually ***reported*** to the utility by customers
- This is how the utility becomes ***aware*** of the failure



Reported Leakage

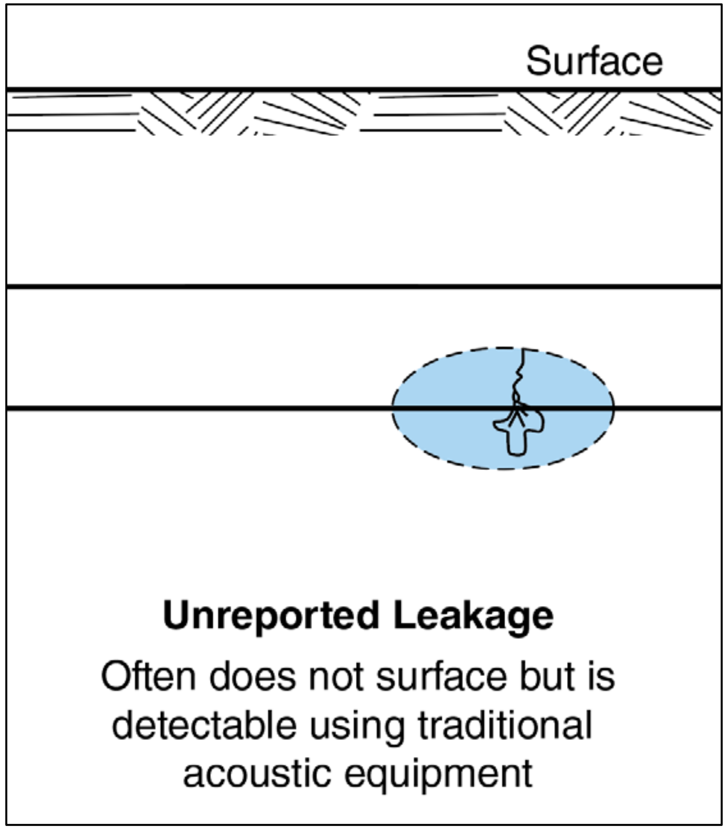
Often surfaces and is reported by the public or utility workers

A. Defining the Types of Leakage

The three types of leakage

I. Unreported Leakage

- Water from leaks or breaks that is **not** visible from above ground
- Often (but not always) low flow events
- It's not visible, so usually **not reported** to the utility
- The utility must take action to become **aware** of unreported leakage; acoustic leak detection and flow measurement are ways to do this



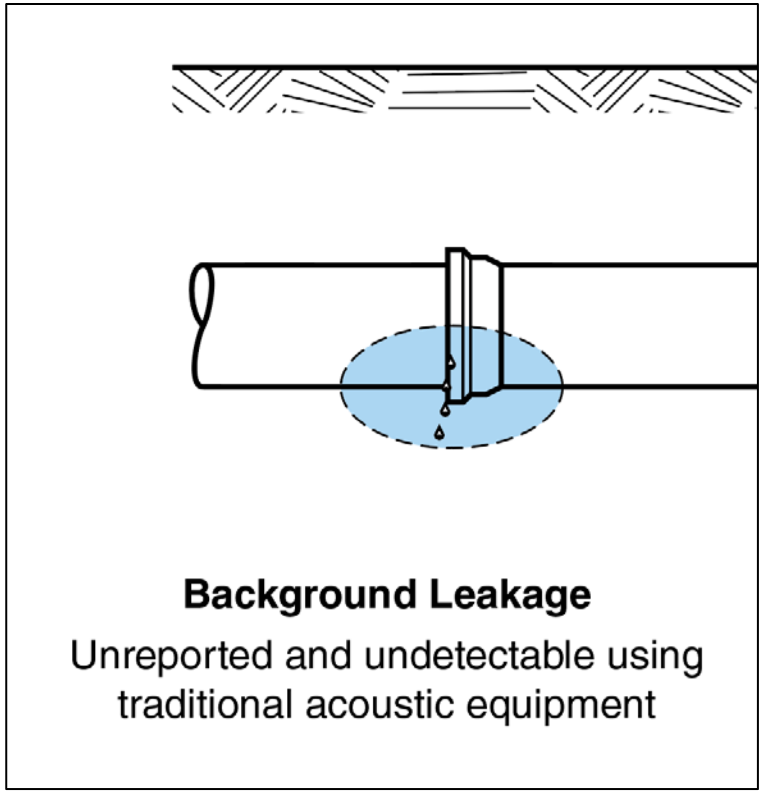
Pipeline graphic from the AWWA M36 Manual

A. Defining the Types of Leakage

The three types of leakage

I. Background Leakage

- Weeps and seeps at joints and fittings that are **not visible** and **not detectable by** acoustic leak detection equipment
- Produce no leak noise
- Very low flow events
- Not cost-effective to excavate to repair
- Sensitive to changes in pressure



Pipeline graphic from the AWWA M36 Manual

A. Defining the Types of Leakage – KNOWLEDGE CHECK

Place a check in the box to the left of the leakage type shown below:

Check Indicator below	Leakage Type
	Reported Leakage
	Unreported Leakage
	Background Leakage

A. Defining the Types of Leakage – KNOWLEDGE CHECK

Which of the three types of leakage is:

- Not detectable by acoustic leak detection equipment?

and

- Is very sensitive to the level of pressure?

A. Reported Leakage
B. Unreported Leakage
C. Background Leakage

A. Defining the Types of Leakage – KNOWLEDGE CHECK

Which of the three types of leakage is:

- The type of leakage that is most commonly addressed by acoustic leak detection?

A. Reported Leakage
B. Unreported Leakage
C. Background Leakage

A. Defining the Types of Leakage

Problems caused by leakage include:

Strain on the system: can't fill tanks, pumps are stressed

Customer complaints: wet basement, low pressure

Damage to streets/property from water main breaks

Wasted water and energy resources; strains ability to grow

EXCESSIVE COSTS ARE INCURRED! LEAKAGE IS <u>NOT</u> FREE!

A. Defining the Types of Leakage

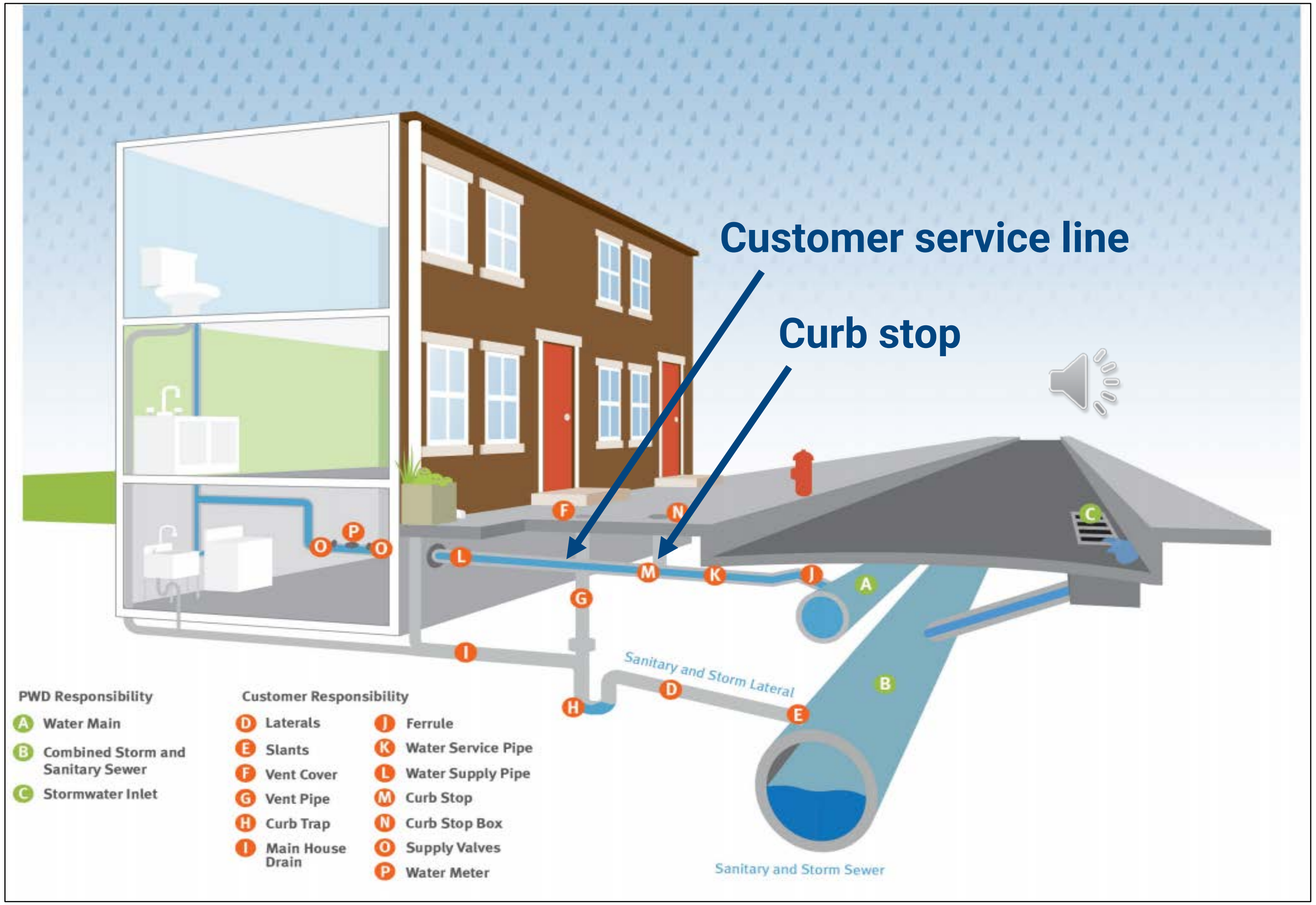
Facts about Customer Service Line Leakage

Customer service line replacement underway

- Monitoring customer service line leakage is important because:
  - Worldwide, most leakage events occur on customer service lines
  - Most of the water lost to leakage originates from customer service line leaks

A. Defining the Types of Leakage

Facts about Customer Service Line Leakage



Water/Sewer Lines & Responsibilities in Philadelphia

- Customer service line repair times
  - For repairs conducted by the water utility: usually a timely response, from 1-10 days
  - For repairs arranged by the customer: often takes much more time to complete and may cause strained customer relations

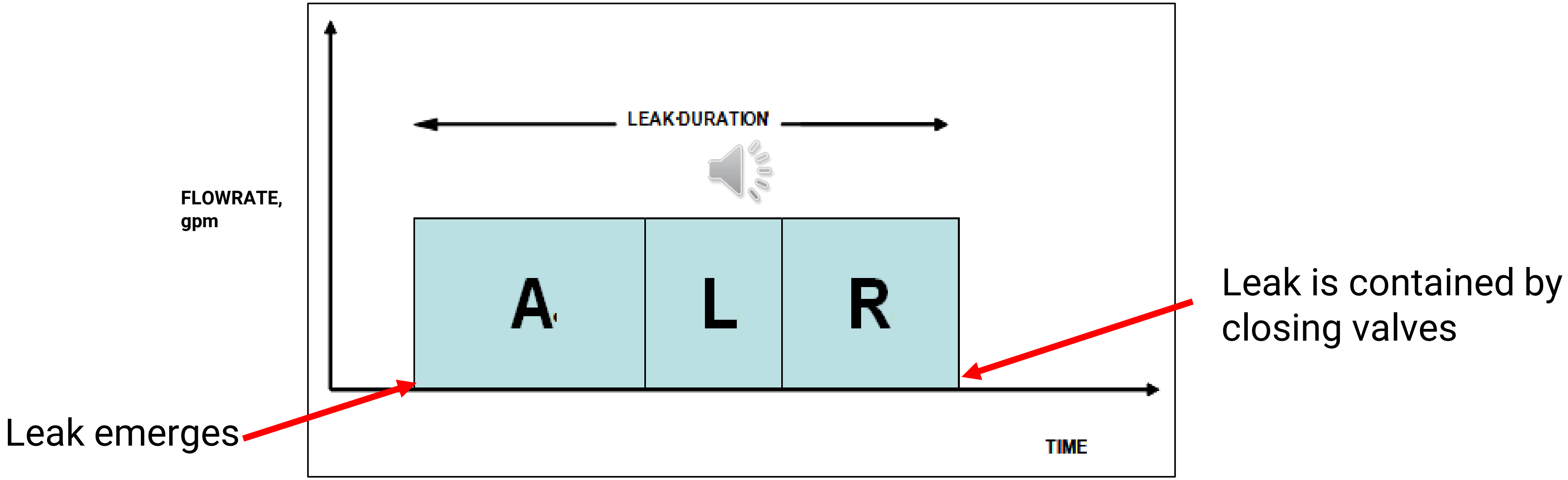
B. The Life of a Leak

MORE LEAKAGE FACTS – REPORTED LEAKAGE

- Utilities respond quickly to reported failures (due to complaints); this keeps leak run time to a minimum
- Reported failures occur less often compared to unreported failures, which are usually greater in number

B. The Life of a Leak

Awareness, Location & Repair Times

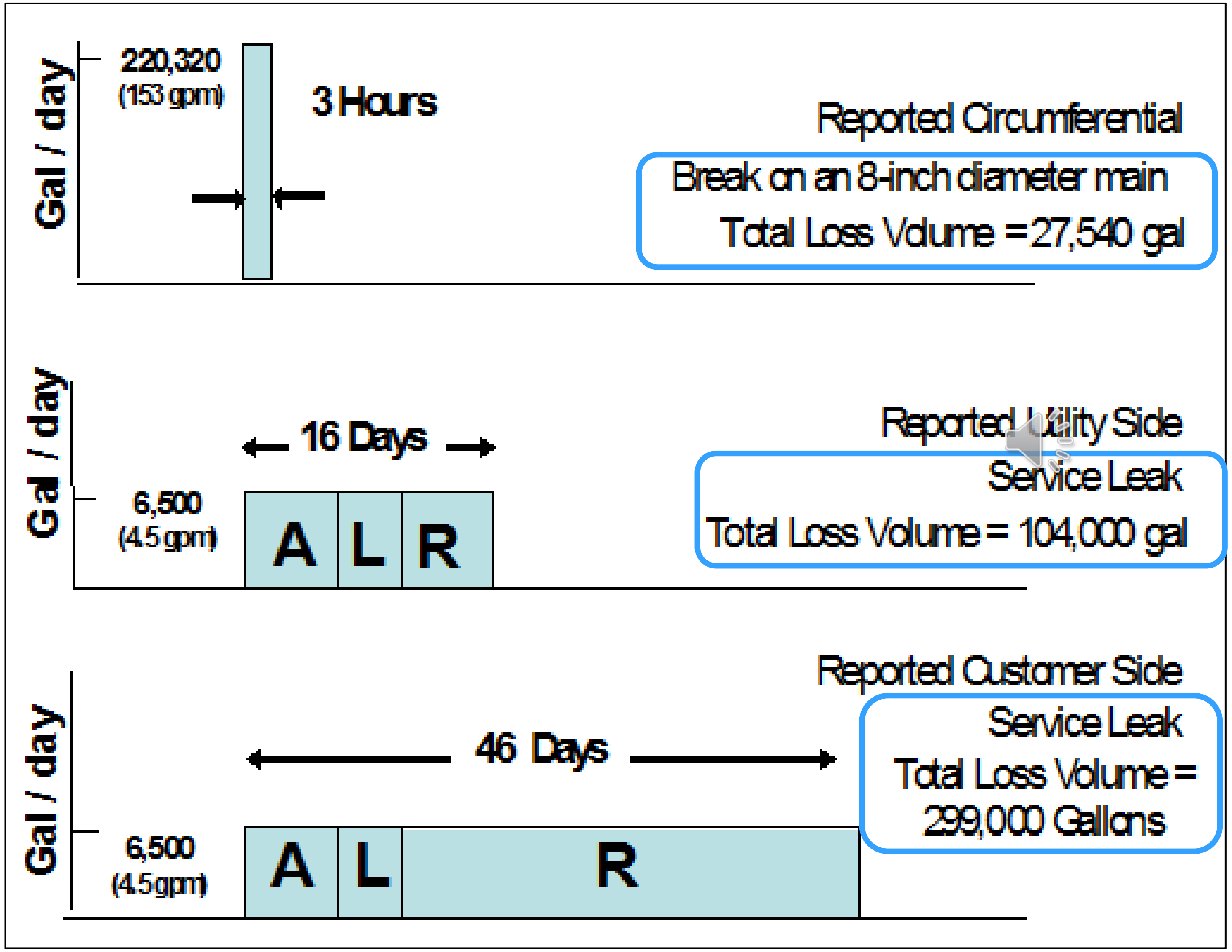


Awareness Time: time for the utility to become aware that new leakage has emerged

Location Time: time to deploy personnel to pinpoint the leak

Repair Time: time to shut-off the water supply in advance of the repair

B. The Life of a Leak



Volumes of Water Lost to Leakage for Different Events

Calculating the volume loss, (V), of a leak:

Use the equation V = Q x T:

V = Leakage rate(Q), gpm x Leak run time(T), minutes

<u>First Example: 8-inch break</u>

V = 153 gpm x 60 min/hour x 3 hr = 27,540 gal

B. The Life of a Leak – KNOWLEDGE CHECK

A water main break erupted in a water utility at 5:30 AM on a recent Sunday morning. Utility staff were able to valve down the break by 10:45 AM on the same morning.

The estimated flow from the water main break was 225 gpm.

Calculate how many gallons were lost due to the break and select from the below:

A. 2,250 gallons
B. 1,181.25 gallons
C. 70,875 gallons
D. 232,875 gallons

B. The Life of a Leak – KNOWLEDGE CHECK

A customer service line leak was detected using acoustic leak detection on May 1st during a regular annual leak survey. The utility doesn't know when the leak started but they survey this area of the distribution system every year. They estimate that the leak ran for one-half of the year since the last survey, or 183 days.

The service line leak flowrate was estimated at 6 gallons per minute, a typical flowrate for a customer service line leak, which often runs in the 4-7 gpm range.

Calculate how many gallons were lost due to the service leak and select from the below:

A. 26,352 gallons

B. 1,098 gallons

C. 1,170,875 gallons

D. 1,581,120 gallons

B. The Life of a Leak

How much water is lost to leakage each year depends on:

- Pipe integrity
- Operating pressure
- Whether soil conditions/road cover allow water to easily surface

And, perhaps most importantly:

- ***The frequency of active leakage control activities by the utility – because this affects the leak run time***

C. The direct and indirect costs of leakage

Do you know how much your leakage is costing you?

Let's see how to figure it out!

C. The Direct and Indirect Costs of Leakage

Water leaked from the distribution system never reaches a customer

Money spent to treat and pump water that leaks is money wasted!

C. The Direct and Indirect Costs of Leakage

- **Direct Costs: operational costs incurred on an ongoing basis**
- **The cost rates that apply include:**

<u>Variable Production Cost (VPC)</u>
If you have your own water supply source

<u>Imported Water Cost Rate</u>
If you purchase bulk water supply

or

<u>Customer Retail Unit Charge (CRUC)</u>
If your water resources are strained (like long-term drought)

C. The Direct and Indirect Costs of Leakage

The Variable Production Costs typically include:

- Water treatment chemicals
- Electric power for pumping
- Other costs may exist

Source: tpo (Treatment Plant Operator)

C. The Direct and Indirect Costs of Leakage

1. **Calculating the VPC: obtain the annual costs listed below:**
   a. **water treatment chemicals**
   b. **electric power for pumping**
2. **Add these costs**
3. **Divide total costs by the annual Water Supplied volume, MG to obtain the VPC in $/MG.**
4. **Multiply the VPC times the annual leakage volume to obtain the annual cost of leakage**

C. The Direct and Indirect Costs of Leakage

Variable Production Cost: example calculation

Consider: a system serving 54,000 people with annual Water Supplied volume of 5,020.5 MG and 194.8 MG of real (leakage) losses

– Annual electric power costs for pumping = $988,000

– Annual cost of water treatment chemicals = $597,500

Total variable costs = $1,585,500

– Variable Production Cost (VPC) = $1,585,500 / 5,020.5 MG = **$315.8 per MG**

– Annual cost of leakage = $315.8/MG x 194.8 MG = **$61,518**

C. The Direct and Indirect Costs of Leakage – KNOWLEDGE CHECK

Quick calculation of the annual leakage cost. A water utility had $70,000 of pumping electric power costs and $30,000 of treatment chemical costs. Its Water Supplied Volume was 200 MG for the year and its leakage volume was 30 MG.

Calculate the VPC and select from below

a. $500 per MG
b. $1,000 per MG
c. $700 per MG
d. $300 per MG

C. The Direct and Indirect Costs of Leakage – KNOWLEDGE CHECK

Quick calculation of the annual leakage cost. We determined that the VPC for the water utility is $500 per million gallons. The annual water audit quantified 30 MG of leakage. Knowing this, answer the below.

Calculate the annual leakage cost and select from below

a. $100,000
b. $6.67
c. $ 2,000
d. $15,000

C. The Direct and Indirect Costs of Leakage

Imported Water Costs:

- Charge paid to purchase bulk water
- Usually a unit charge (Ex: dollars per 1,000 gallons)
- Imported water is typically expensive (compared to self-supplied water)

Imported water supply flowmeters

C. The Direct and Indirect Costs of Leakage

Applying the Customer Retail Unit Cost to Leakage

- The Customer Retail Unit Charge (CRUC) can be applied to leakage if source water resources are stressed.
- The CRUC is commonly applied to apparent losses, but can be applied to real (leakage) losses in some cases
- ***If the CRUC is applied, leakage becomes very expensive!***

C. The Direct and Indirect Costs of Leakage

Indirect Costs

- **Strain on the water system to meet water demands**
- **Impacts to the community or environment**

Examples of indirect cost impacts that result from leakage:

Liability costs from damage caused by leaks and water main breaks	Strain on water treatment plant and pumping capacity	Excessive water withdrawals that strain water allocations and possibly limit growth in the region

C. The Direct and Indirect Costs of Leakage

Benefits of Leakage Management

- Decrease source water needs including imported water
- Reduce water treatment costs
- Fewer system disruptions
- Extend water distribution system life
- Compliance

Lake Oroville, CA Reservoir

C. The Direct and Indirect Costs of Leakage – KNOWLEDGE CHECK

True or False:
Leakage has no cost associated with it.

TRUE

FALSE

C. Review Direct Costs of Leakage: KNOWLEDGE CHECK

Which of the below costs is <u>not</u> a direct variable cost of leakage?

a. Electric power for water pumping

b. Employee salaries

c. Water treatment chemicals

Module 1 Summary

Leaks occur due to stresses in the environment exceeding the structural capacity of piping. Leaks occur as three types: reported leaks, unreported leaks, and background leakage.

Understanding the “life of a leak” allows us to find ways to keep this "life" to a minimum.

Leakage has costs, and we can define these costs and their impacts.

Various techniques exist to control leakage – we’ll discuss them next in Module 2

MODULE 2

Proactive Leakage Management

Module 2
Proactive Leakage Management
Agenda

A. Identifying the Signs of Increasing Leakage

B. Acoustic Leak Detection

C. Flow Measurement in District Metered Areas

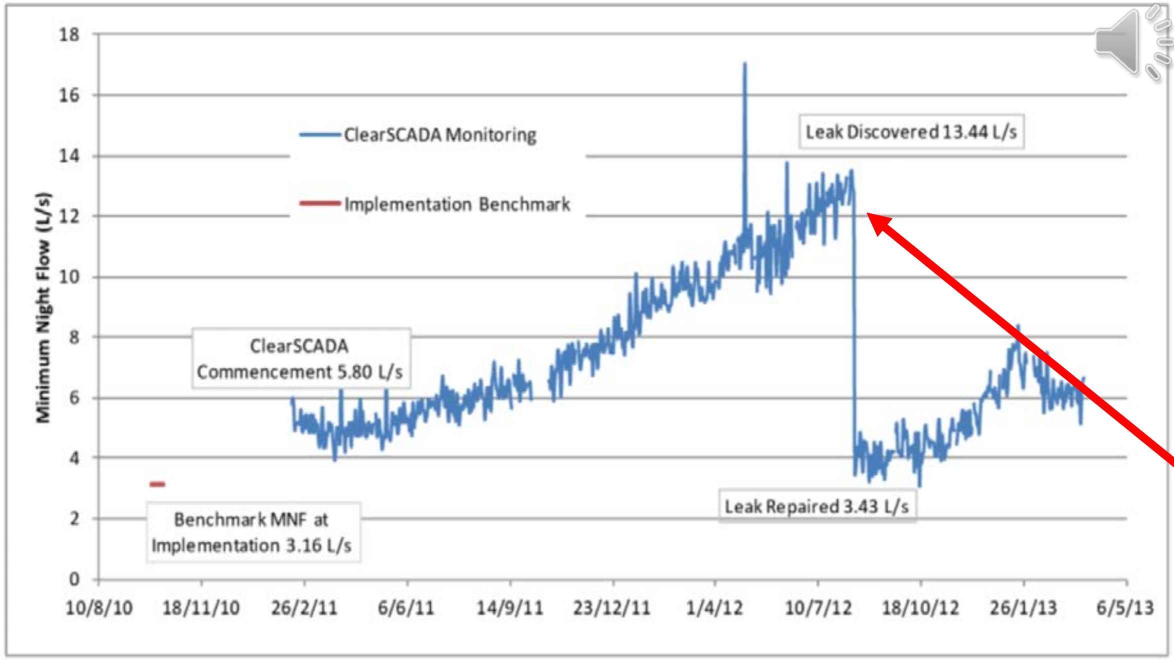
Module 2 Learning Objectives

As a result of this module participants should be able to:

1. Identify the signs of increasing leakage
2. Apply acoustic leak detection to identify hidden leaks
3. Interpret flows measured in District Metered Areas to flag emerging leakage

A. Identifying the Signs of Increasing Leakage

Some signs of leakage are easy to spot



Flow measured in litres per second

Some signs of leakage are not visible to the public

Flow measured in a portion of the distribution system increased due to an emerging leak

A. Identifying the Signs of Increasing Leakage

Water tank holding 6 million gallons of storage

Other signs of emerging leakage include:

- Difficulty in filling water tanks
- Low pressure in parts of the service area
- High production/pumping flowrates

A. Identifying the Signs of Increasing Leakage

What type of leakage management do you use?

Reactive Leakage Management: wait until water is visible then fix it

or

Proactive Leakage Management: look for hidden leaks and fix them when they are small

A. Identifying the Signs of Increasing Leakage: KNOWLEDGE CHECK

Which of the below is <u>not</u> an indication of new leakage forming?

a. A water tank is filling slower than normal
b. Treatment plant effluent pump rates are elevated
c. System water pressures are higher than normal
d. System water pressures are lower than normal

A. Identifying the Signs of Increasing Leakage – KNOWLEDGE CHECK

Which type of Leakage Management waits for leaks to appear, and then fixes them?

Reactive Leakage Management

Proactive Leakage Management

B. Acoustic Leak Detection

Acoustic Leak Detection is the most common type of leakage control in use

It is affordable and equipment is commonly available

Leak Correlator equipment used to pinpoint leaks

The utility can conduct leak detection themselves or hire a skilled contractor

All water utilities should regularly conduct acoustic leak detection!

B. Acoustic Leak Detection

Acoustic leak detection has been in use of over 100 years and began using simple listening sticks!

Principles of acoustic leak detection:

- Water in pressurized pipe makes a noise (leak noise) when water escapes the pipe
- The strength of the noise depends on several factors
- Equipment exists to detect leak noise and assist in pinpointing its source

B. Acoustic Leak Detection

Acoustic leak detection steps

1. Listening survey – conduct soundings across the distribution system
   - Acoustic microphone
   - Geophone
   - Leak Noise Loggers – automates the process
2. Leak Pinpointing – identify source of leakage
   - Geophone
   - Leak correlator

Sounding a valve key touching a valve

Acoustic microphone

Geophones in use

B. Acoustic Leak Detection

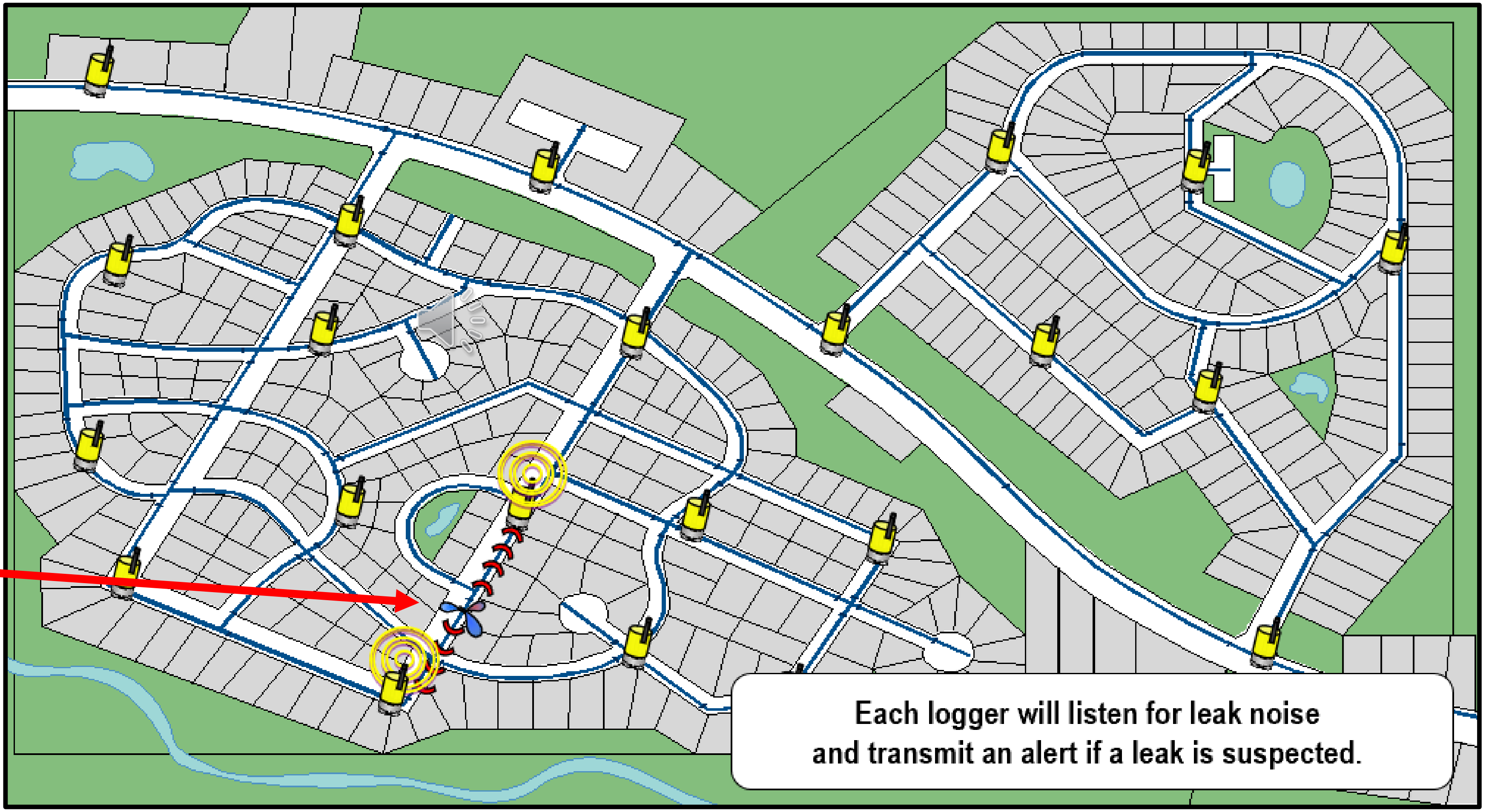
Continuous Acoustic Monitoring (CAM) using Leak Noise Loggers

Loggers are attached to fire hydrants, valves, or customer service connections

Loggers awaken at night to record noise which is then analyzed

Noise detected by two or more nearby loggers is likely a leak

Some systems detect leak noise and correlate to pinpoint the leak



Graphic courtesy of 540 Technologies

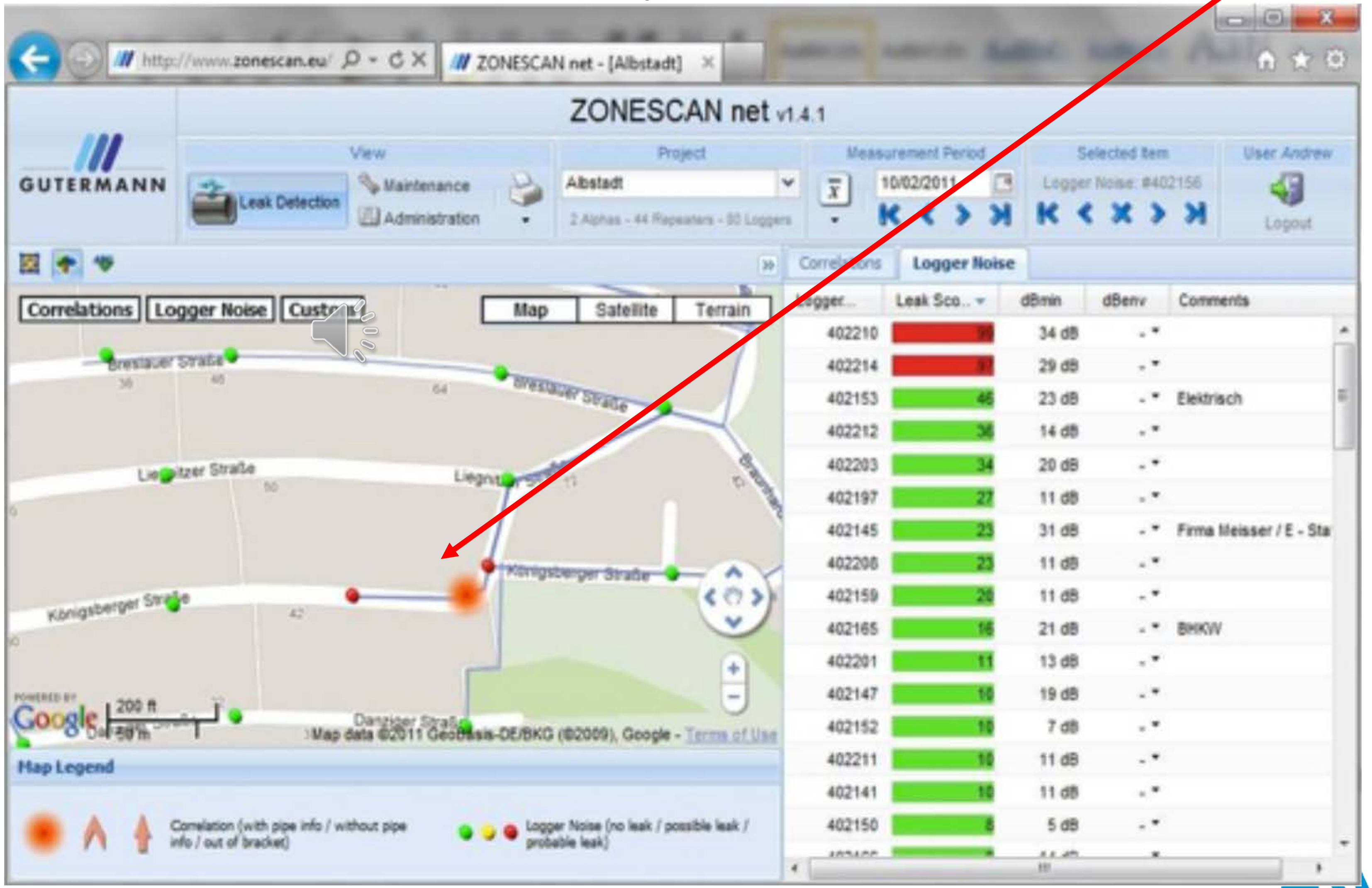
B. Acoustic Leak Detection

Continuous Acoustic Monitoring (CAM)

Permanently mounted acoustic logging systems: Sensing and correlation

Hydrophone retrofitted to fire hydrant base *Courtesy of Digital Water Solutions*

Leak noise monitors help to automate the leak survey process and display leak candidates daily
Courtesy of Gutermann



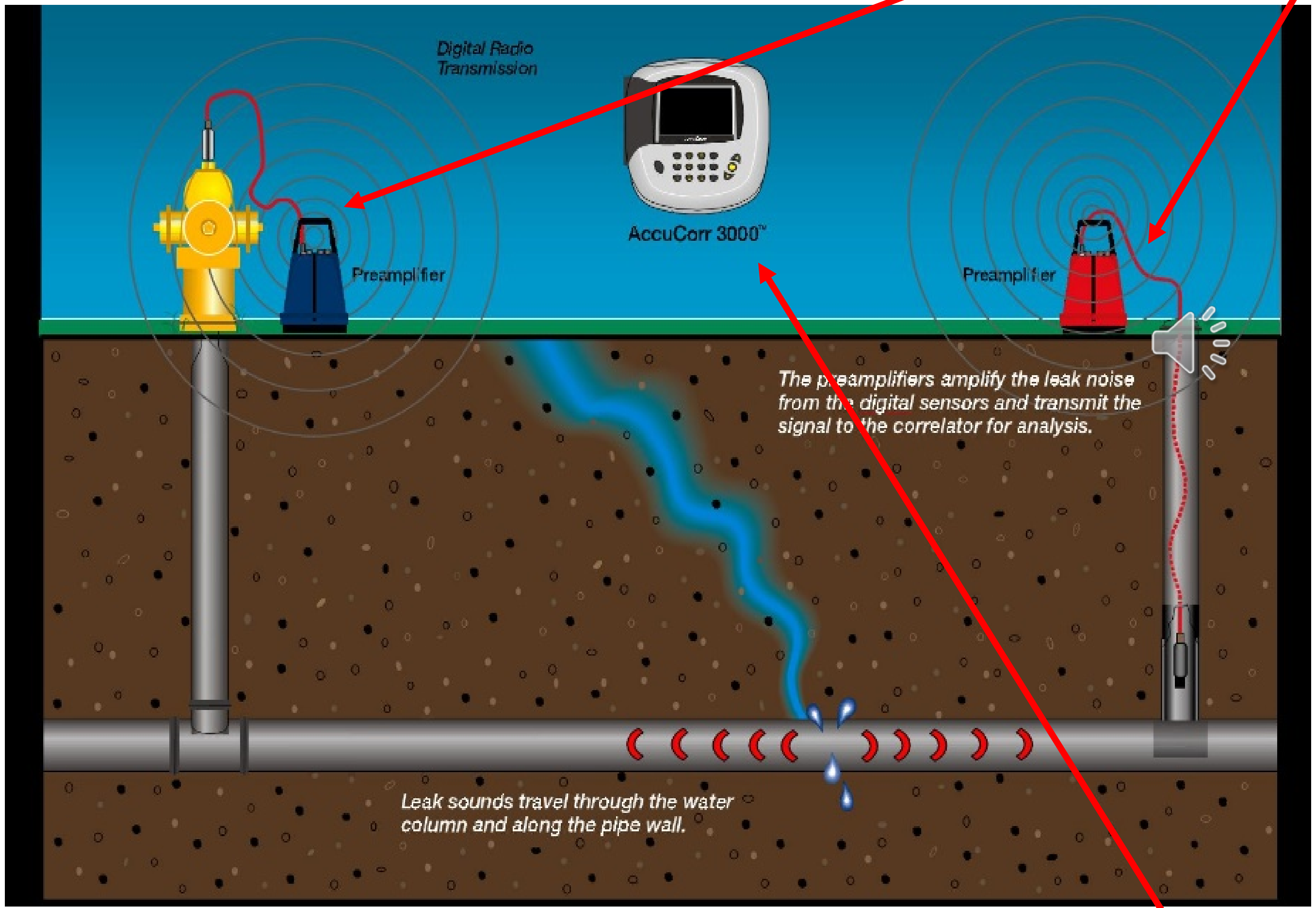
B. Acoustic Leak Detection

Leak Correlation – pinpointing the leak source

Leak sensors are placed on either side of the suspected leak and in contact with the water main.

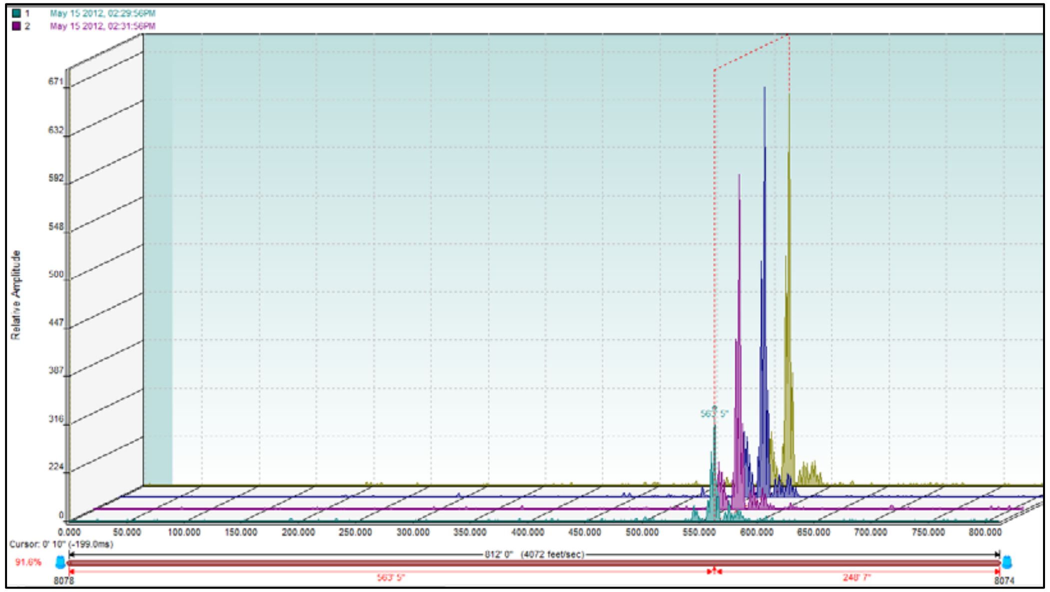
The distance between the sensors and the pipe material are input into the correlator.

The sensors radio the leak noise signals to the leak correlator, which computes the location of the leak.



Graphics courtesy of 540 Technologies

Leak Correlator



Correlator display showing steep peaks on graphs indicating strong correlation levels at the location of the leak

B. Acoustic Leak Detection

Leak Correlation – the importance of accurate leak pinpointing

Visible water on the street surface doesn't always mean that location is the source of the leak

"Dry Holes" (to be avoided)

B. Acoustic Leak Detection – KNOWLEDGE CHECK

Which of the two primary steps of acoustic leak detection first covers the water distribution system to detect leak noises

Listening Survey

Leak Pinpointing

B. Acoustic Leak Detection

Factors Producing **Audible** Leak Noise	Factors Producing **Weak** Leak Noise
• High water pressure	• Low water pressure
• Hard backfill	• Soft backfill
• Hard ground cover (paved surfaces)	• Soft ground cover (vegetated surfaces)
• Clean pipe	• Encrusted pipe
• Low flowrate rupture	• High flowrate rupture
• Metallic pipes	• Soft (plastic)/lined pipes
• Small diameter pipes, 12-inch and smaller	• Large diameter pipes, larger than 12-inch

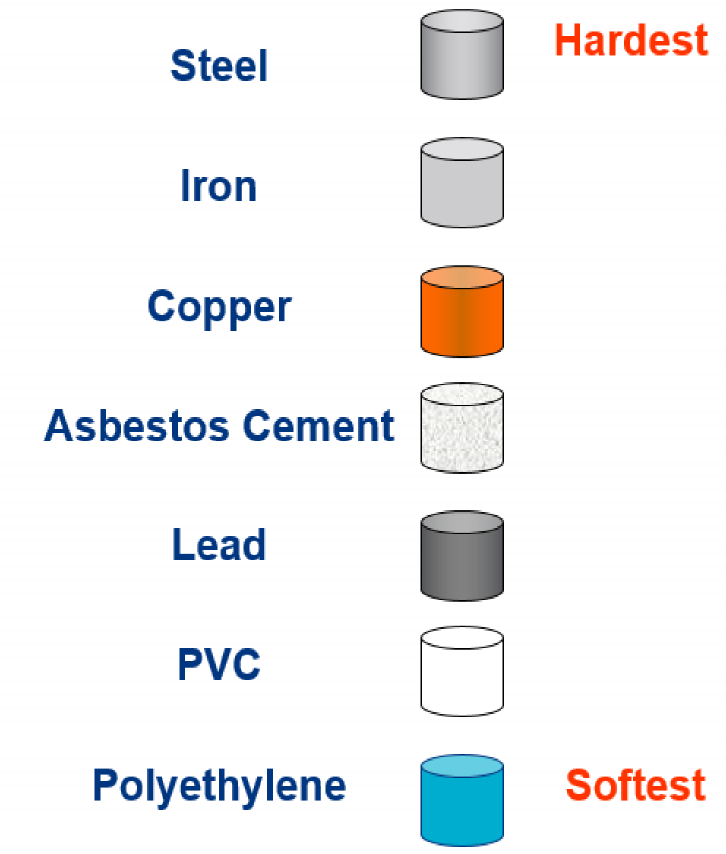
Slide courtesy of 540 Technologies

B. Acoustic Leak Detection

Leak Noise Factors – Pipe Materials

- Metal Pipe (steel, iron, copper) is rigid and transmits strong leak noise
- Plastic pipe (Polyvinyl Chloride or PVC, Polyethylene) is flexible and does <u>not</u> transmit leak noise well
- Asbestos cement and lead pipe fall between metal and plastic pipe in transmitting leak noise

Typical Pipe Materials



Graphic Courtesy of 540 Technologies

B. Acoustic Leak Detection

Leak Detection challenges – conflicting noise sources

- Customer water usage
- Pressure Reducing Valves (PRV's)
- Partially closed valves (throttled or passing)
- Partial obstruction of pipe bore (presence of a foreign object)
- Proximity of water main to sewer/culvert pipe
- Changes in pipe diameter
- Water pumping
- Electrical interference
- Pipe lining

Operator skill is critical to distinguish sounds

B. Acoustic Leak Detection

Conducting Acoustic Leak Detection

- Doing leak detection in-house
  - Funding
  - Staff (assigned full-time or part-time)
  - Equipment: geophones, acoustic microphone, leak correlator, and leak noise loggers
  - Training
  - Procedures, deployment schedule, documentation
  - $5,000 - $25,000 upfront costs
- Leak Detection contractors: $250-$450/mile of pipeline surveyed
- Frequency: cover entire system every 1-5 years
- **DON'T FORGET TO CONDUCT TIMELY, QUALITY LEAK REPAIRS**

Small systems – may be best to consider hiring a leak detection contractor!

B. Acoustic Leak Detection: KNOWLEDGE CHECK

Which of the below conditions represent the most difficulty in detecting leaks on water piping:

a. Small diameter cast iron pipe in hard fill under a road
b. Asbestos cement pipe with high pressure
c. PVC pipe buried in loose fill under vegetation on the side of a road
d. An exposed pipe within the superstructure of a bridge

B. Acoustic Leak Detection: KNOWLEDGE CHECK

Match the acoustic leak detection equipment in the left box with the function that it performs in the right box:

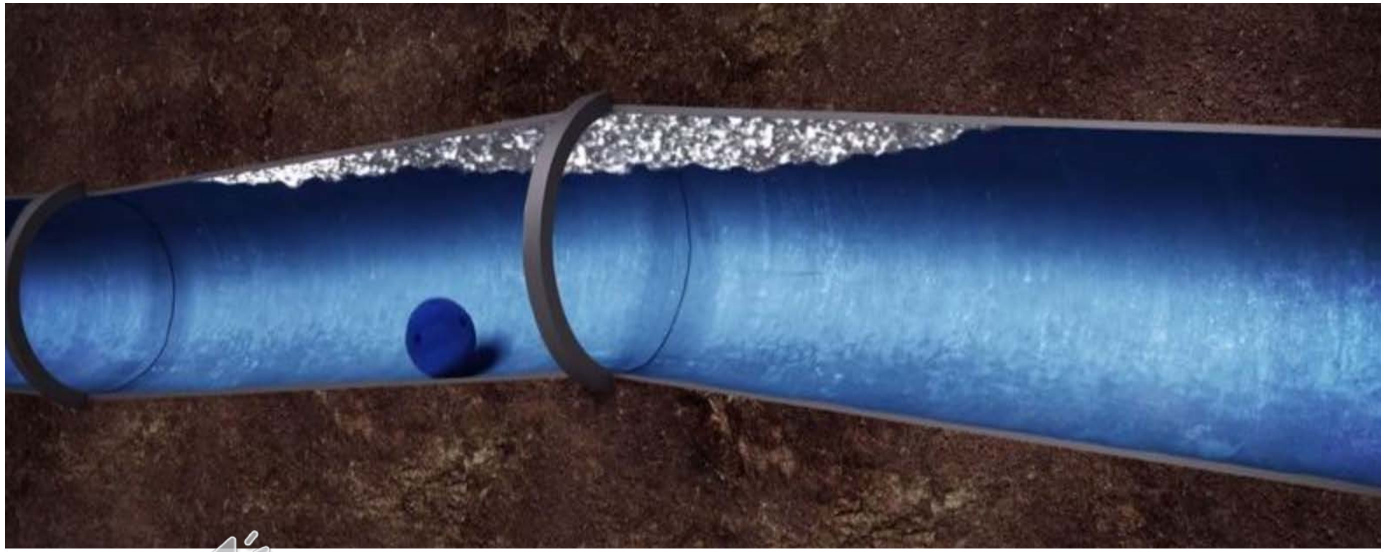
A. Geophones
B. Correlator
C. Acoustic Microphone
D. Leak Noise Logger

___ Automated electronic sounding & recording
___ Electronic sounding
___ Manual leak sounding and pinpointing
___ Electronic leak pinpointing

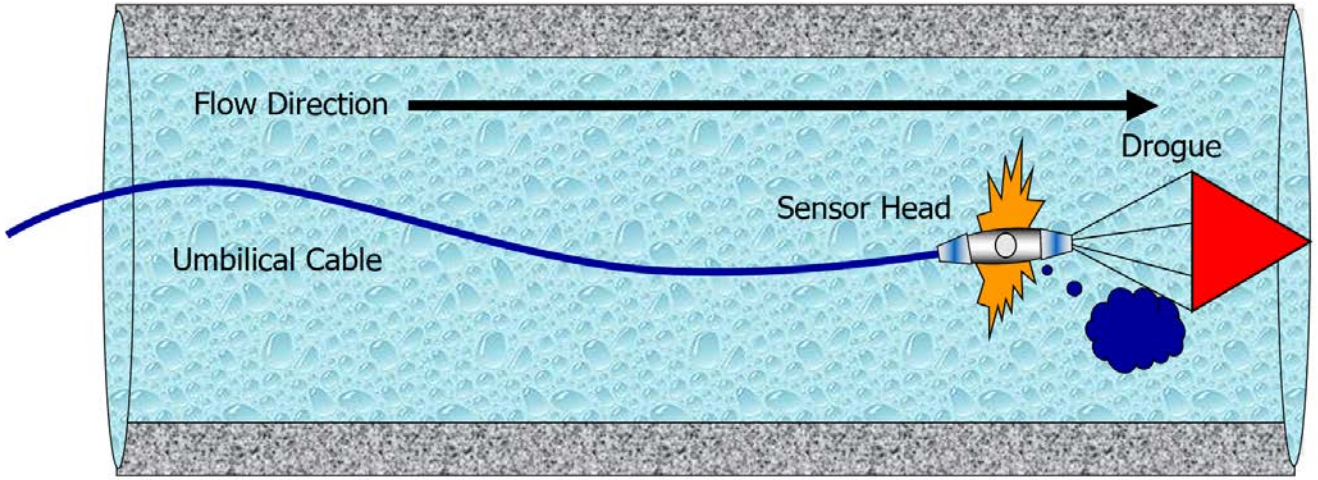
B. Leak Detection – High Tech Solutions

Inline leak detection

- Acoustic sensor travels inside the pipeline
- Interfering noise is not a factor
- Pipe access and logistics require careful planning



Smartball® "free swimming" sensor
Source: Pure Technologies/Xylem



Sahara® technology – tethered device
Source: Pure Technologies/Xylem

High Tech Leak Detection

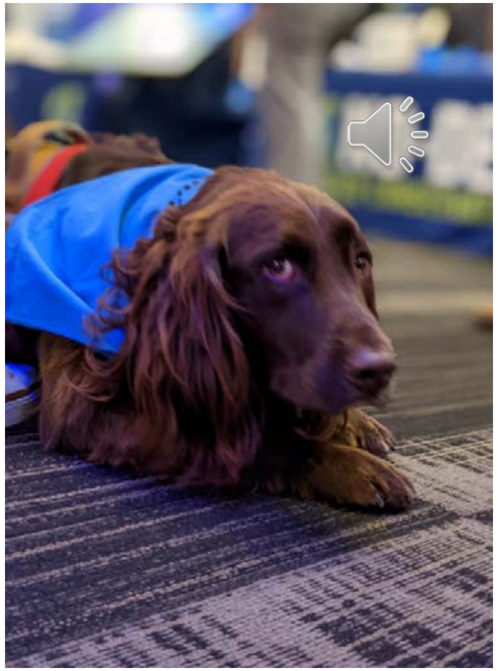
Satellite leak detection image
Source: Asterra

Satellite leak detection

- Uses synthetic aperture radar technology
- Wide-area scans conducted
- “Points-of-interest” are identified
- “Hit rate” of this technology is still being evaluated

Low Tech Leak Detection – Sniffer Dogs

"Vessel" Arkansas

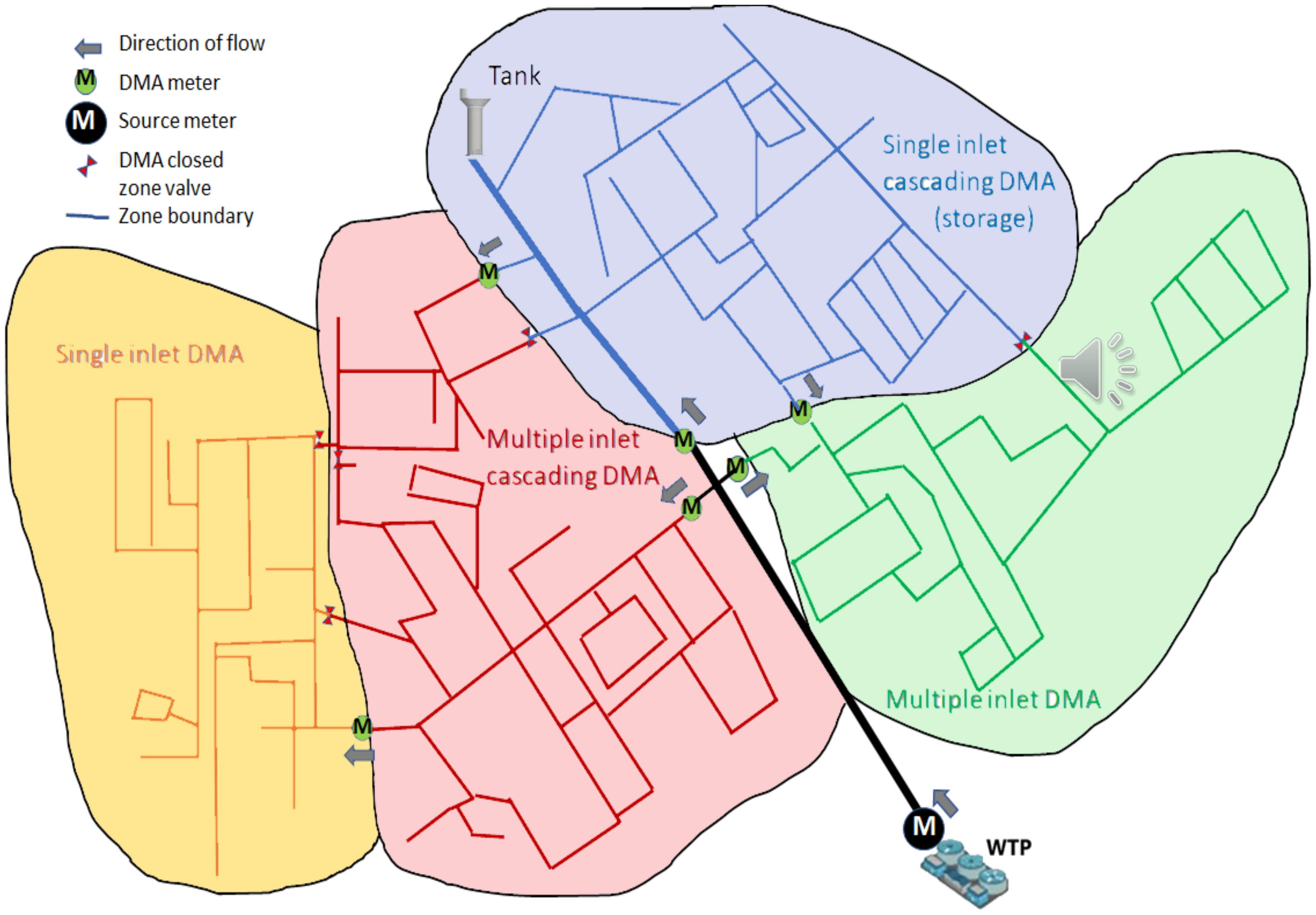


"Gauge" Tennessee

Sniffer dogs originated in the United Kingdom but are being trained in other countries and are being used with great success!

C. Flow Measurement in District Metered Areas

Definition of District Metered Area or DMA

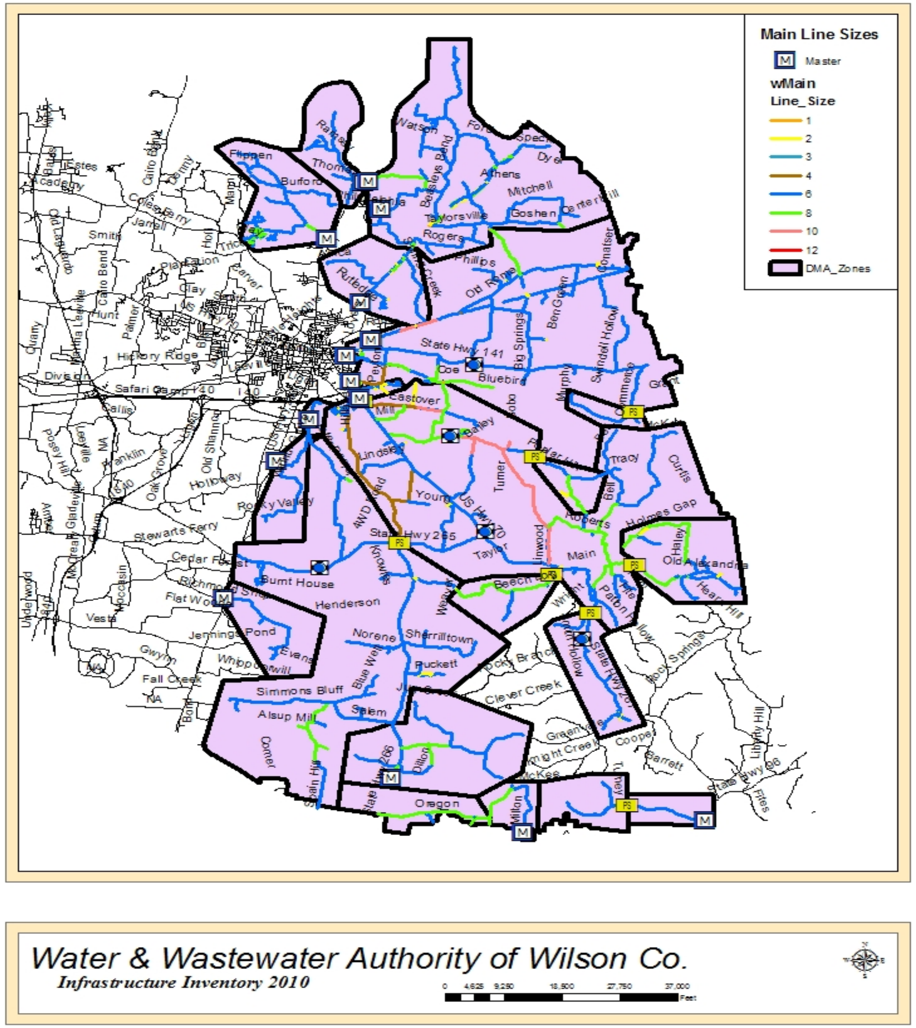


General configurations of District Metered Areas

- DMA – a small discrete zone with water supply continuously monitored via one or two supply lines outfitted with flowmeters
- During the minimum consumption period (often night-time), leakage is at the highest proportion of the demand
- Minimum consumptions analysis reveals leakage rate
- Leakage rates can be measured – in a DMA!

C. Flow Measurement in District Metered Areas

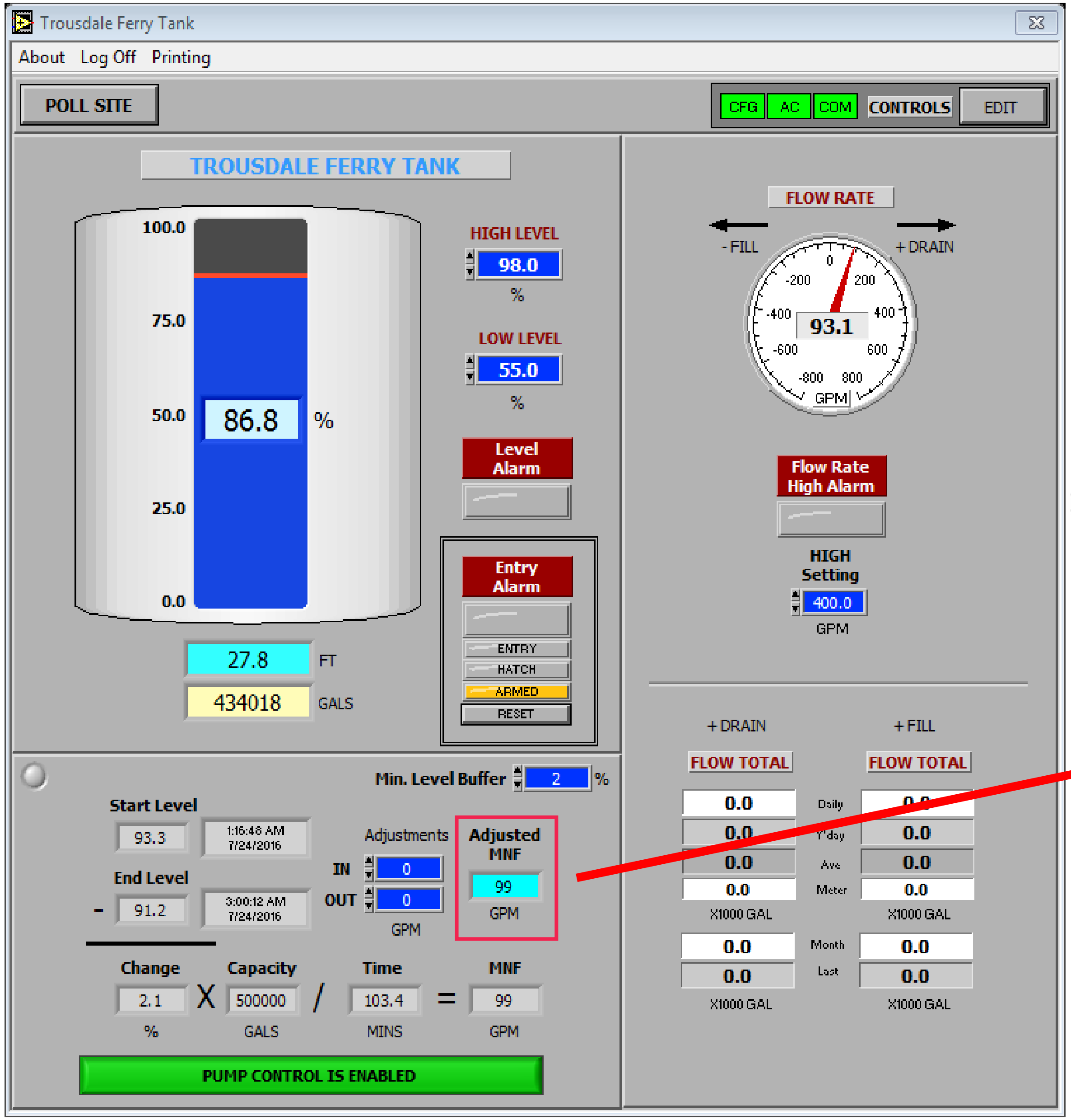
DMA Case Study: Water & Wastewater Authority of Wilson County, TN (WWAWC)



- WWAWC supplies water to roughly 7,400 service lines via 342 miles of piping
- WWAWC purchases (imports) its entire water supply at an expensive rate of $2,590 per million gallons
- With expensive water, leakage management is a high priority
- With a 100% PVC piping system, WWAWC created DMAs across the entire system

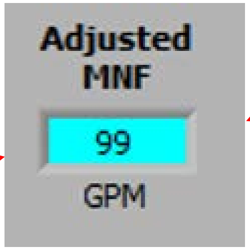
Note: it is not necessary to create DMAs in your entire system! Start with one or two in the highest leakage areas.

C. Flow Measurement in District Metered Areas



DMA Case Study: Water & Wastewater Authority of Wilson County, TN (WWAWC)

WWAWC Supervisory Control & Data Acquisition (SCADA) System - Trousdale Ferry DMA

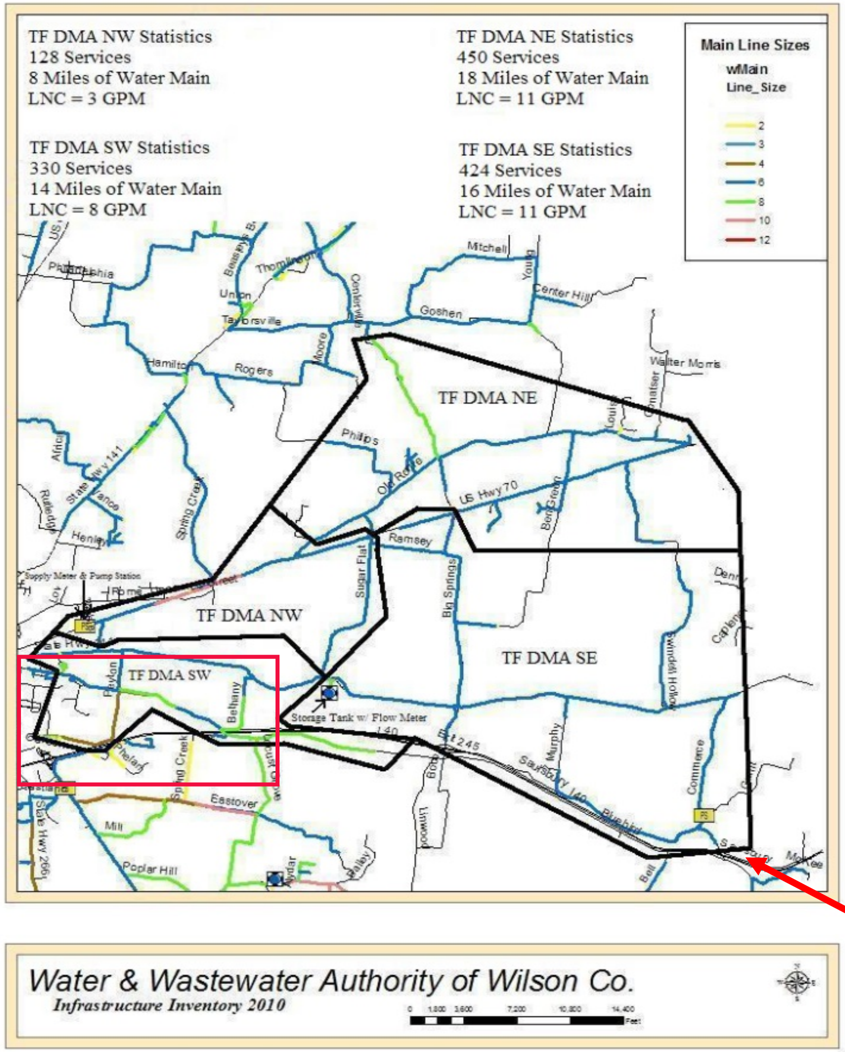


WWAWC experienced an elevated Minimum Night Flow (MNF) of 99 gallons per minute (gpm).

First Step: WWAWC knows from flow tracking that a flowrate over 53 gpm is excessive. At 99 gpm, a leak investigation was needed.

C. Flow Measurement in District Metered Areas

DMA Case Study: Water & Wastewater Authority of Wilson County, TN (WWAWC)



<u>Second Step</u>: conduct ***Step-Testing*** by closing valves to temporarily shutdown sections of the DMA.

If DMA flow drops when a section is shutdown, this confirms the leak originates in this section.

Staff step-tested 56 miles of piping in less than three hours; the leak was localized to a 4,900’ area in the SW sub-section

<u>Third Step</u>: acoustic leak detection was conducted in the SW sub-section of the DMA.

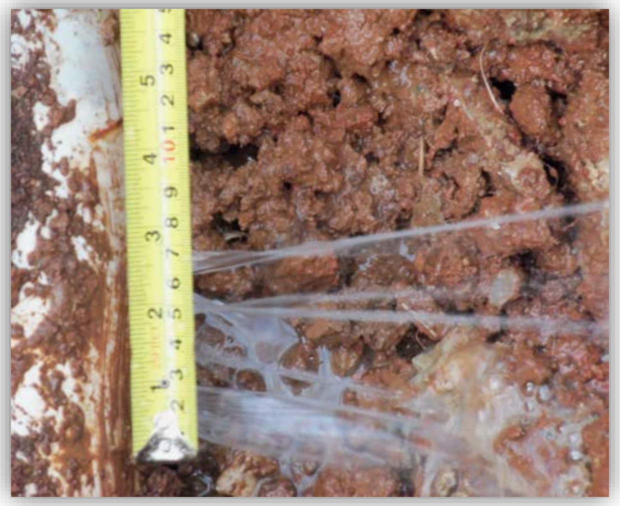
Four sections used for step-testing; SW sub-section highlighted

C. Flow Measurement in District Metered Areas

DMA Case Study: Water & Wastewater Authority of Wilson County, TN (WWAWC)

No leak noise detected on valves and service lines within 340 feet of the leak source.

Leak noise was audible only by acoustic (ground) microphone at the leak location.

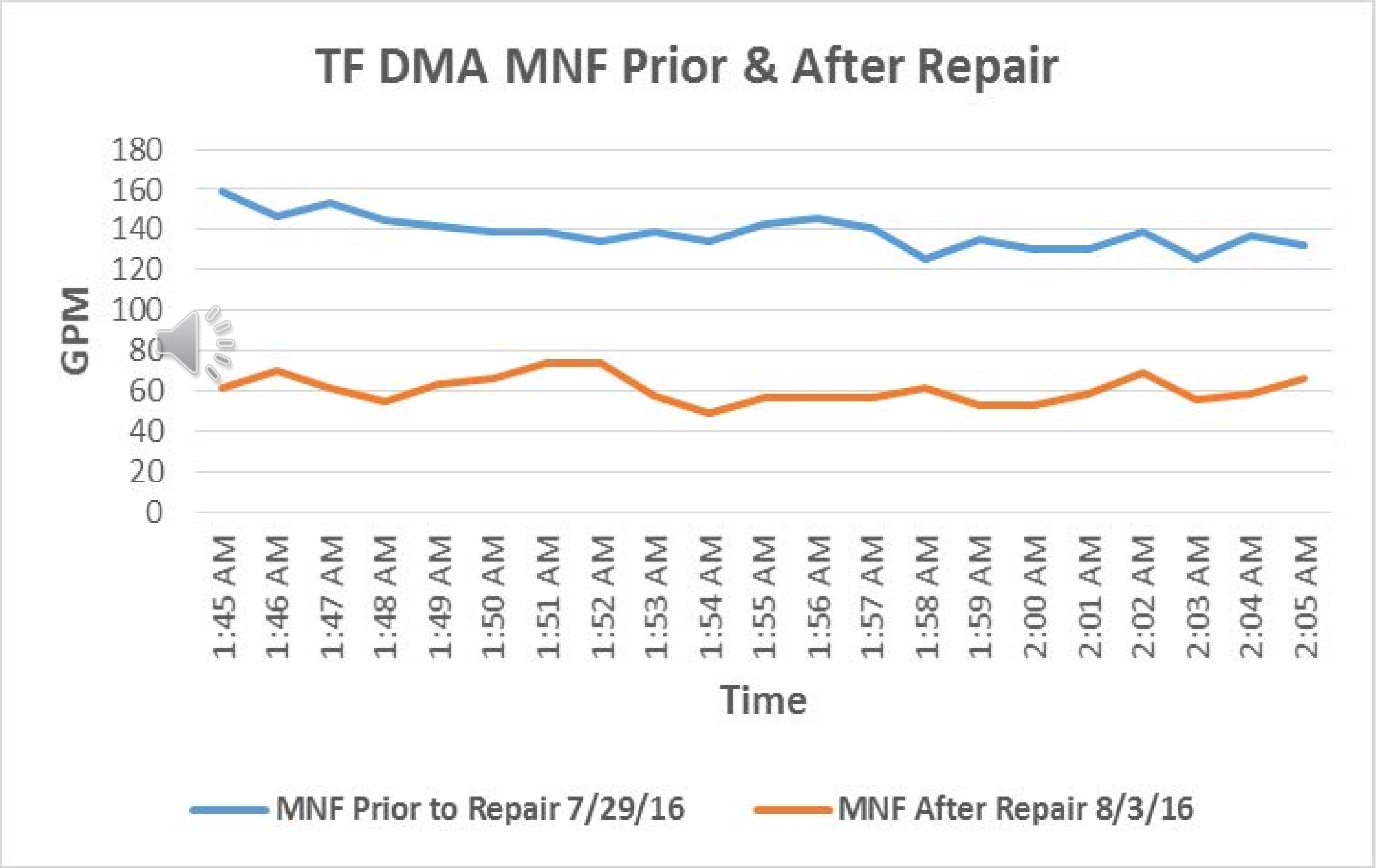


C. Flow Measurement in District Metered Areas

DMA Case Study: Water & Wastewater Authority of Wilson County, TN (WWAWC)

Leak Detection Process:

- The leak was alerted, investigated, pinpointed, and repaired within six days
- 6-inch PVC water main located under vegetated cover, 20 feet off road, at 50 psi
- No water was surfacing or visible
- No low pressure complaints
- Not detectable by direct contact sounding on system valves, hydrants, or services
- Notable savings in reduced leakage



Trousdale Ferry Minimum Night Flow (MNF)
Change in MNF after repair of leak

C. Flow Measurement in District Metered Areas – KNOWLEDGE CHECK

True or False: there is no way to measure leakage flowrates?

True

False

C. Flow Measurement in District Metered Areas: KNOWLEDGE CHECK

Match the term in the left to the definition listed in the right box:

A. Minimum Night Flow

B. Step-Testing

C. District Metered Area

___ The process of temporarily valving closed a zone or area to observe a change in leak flowrate.

___ A zone established with one or two supply mains and supply measured by a flowmeter. Use to obtain alerts of new leakage.

___ The rate of flow occurring in the night hours when most customer water demand is at a minimum and leakage is at the greatest proportion of the flow.

C. Acoustic Leak Detection and District Metered Areas (DMA)

Utilities can use both acoustic leak detection and DMAs; it doesn't need to be "one-or-the-other"

Acoustic Leak Detection

- Strengths
  - Equipment/training readily available
  - Affordable
  - Locates and pinpoints leaks
- Limitations
  - Can be labor intensive
  - Early alert of new leakage only with loggers
  - Does not give a leak flowrate
  - Difficult to conduct on plastic piping

- Leak detection contractor may be best for small systems

District Metered Areas (DMA)

- Strengths
  - Gives early alert of new leakage
  - Provides leak flowrate
  - Localizes the leak
- Limitations
  - Does not pinpoint leaks
  - Requires flowmeter
  - Not feasible in all areas (large water users, large transmission pipelines)

Module 2 Summary

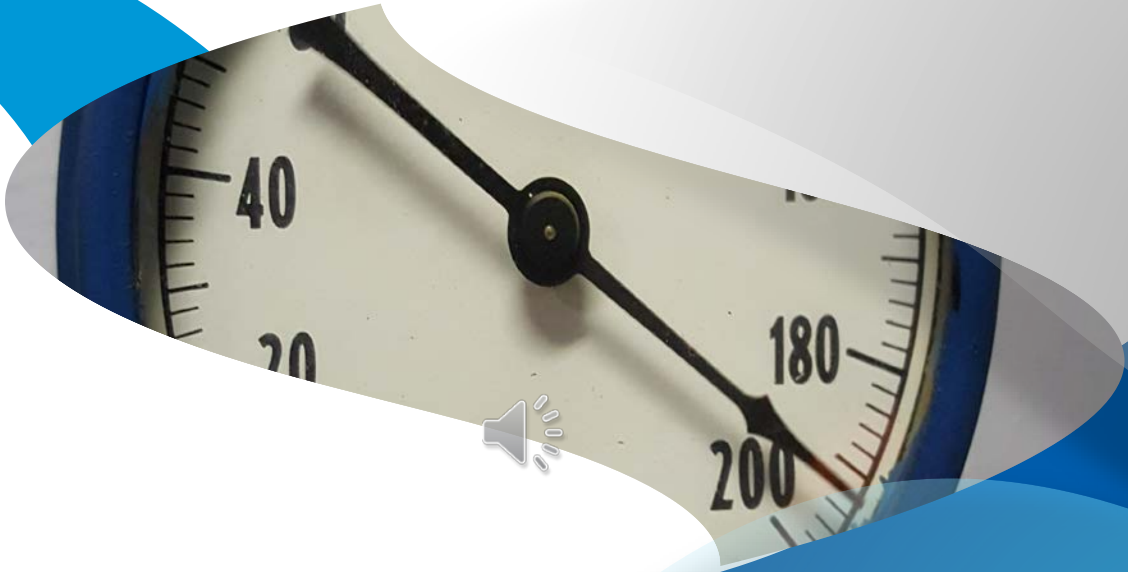
Leakage can be identified visually or indirectly by acoustic sounding or flow measurement, but most leaks are not visible

Acoustic leak detection is the most accessible and affordable leakage control technology available

Flow measurement in District Metered Areas can alert you to newly rising leakage to assist in containing leak run time

Another important technique is pressure management – we'll talk about it in Module 3

MODULE 3



Pressure Management Benefits and Applications

Module 3

Pressure Management Benefits and Applications

Agenda

A. How Pressure Levels Vary in Water Systems

B. The Impacts of Excessive Pressure

C. Pressure Management Overview

Learning Objectives

As a result of this module participants should be able to:

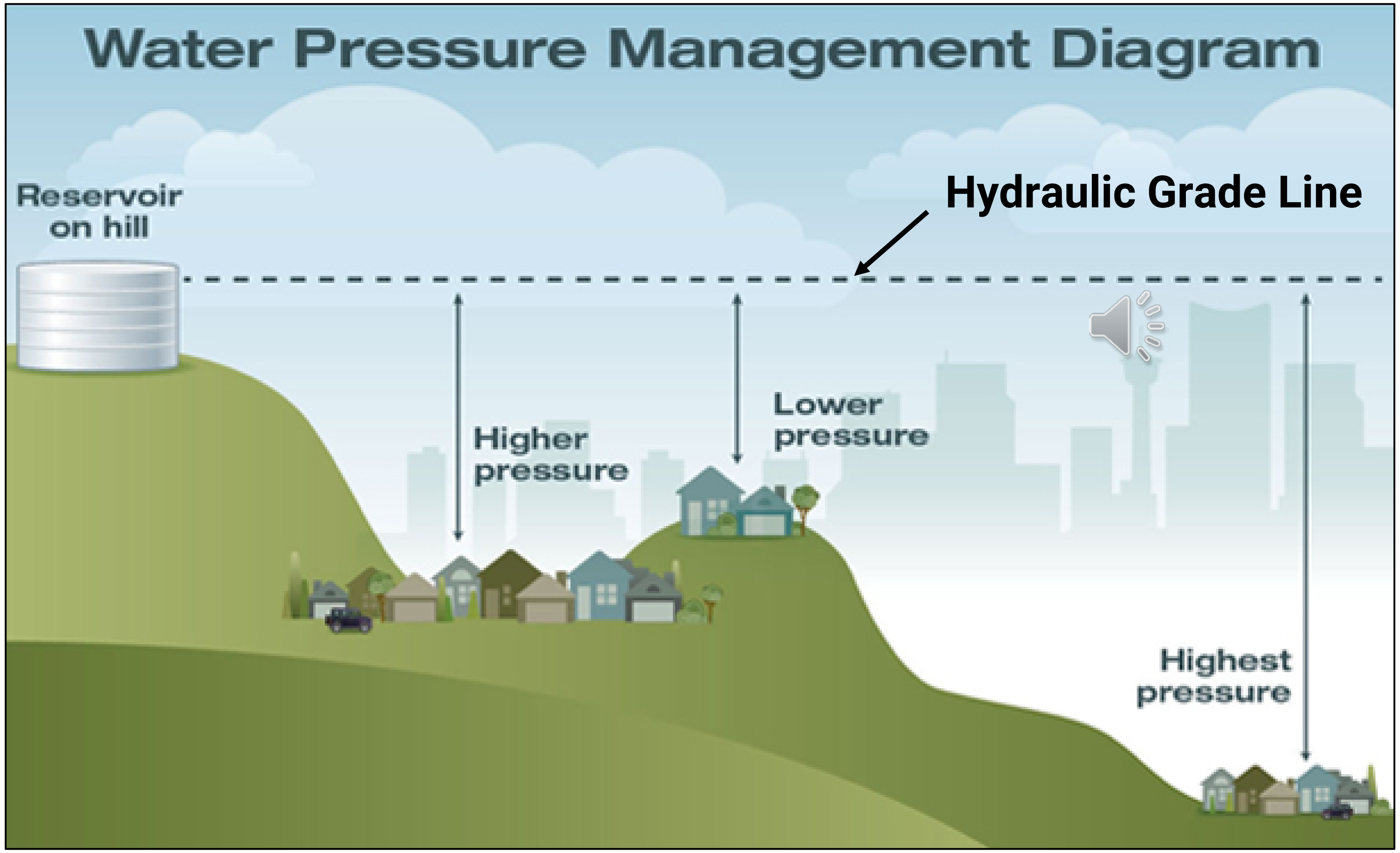
1. Explain the important role that water pressure plays in the occurrence of leakage

2. Explain why too much pressure is a bad thing

3. Identify several methods of pressure management that can help to control leakage and slow water main breaks

A. How Pressure Levels Vary in Water Systems

Why different pressure levels exist in water distribution systems



Graphic courtesy of 540 Technologies

Pressures vary because ground

Water must be pumped at high pressure to reach storage tanks or customer buildings at higher elevations

Pipelines that move water to higher ground often go through areas of lower elevation

In the low elevation areas, pressure in the pipeline can be very high

A. How Pressure Levels Vary in Water Systems

Why different pressure levels exist in water distribution systems

Pressure Ranges

20 psi: - recognized minimal level, but 35-40 psi is a better minimal range to ensure reliable water service to customers

60 – 80 psi is a good overall range for service to customers

How much pressure is too much?

Some USA state regulatory agencies discourage pressure above 125-150 psi, but this may be hard to avoid in systems with hilly terrain.

If customers have a Pressure Reducing Valve (PRV) on their service line, the incoming pressure is higher than the customer needs for adequate service.

This may mean that pressure in your distribution system is high. If pipelines were not designed to withstand this pressure, failures can occur.

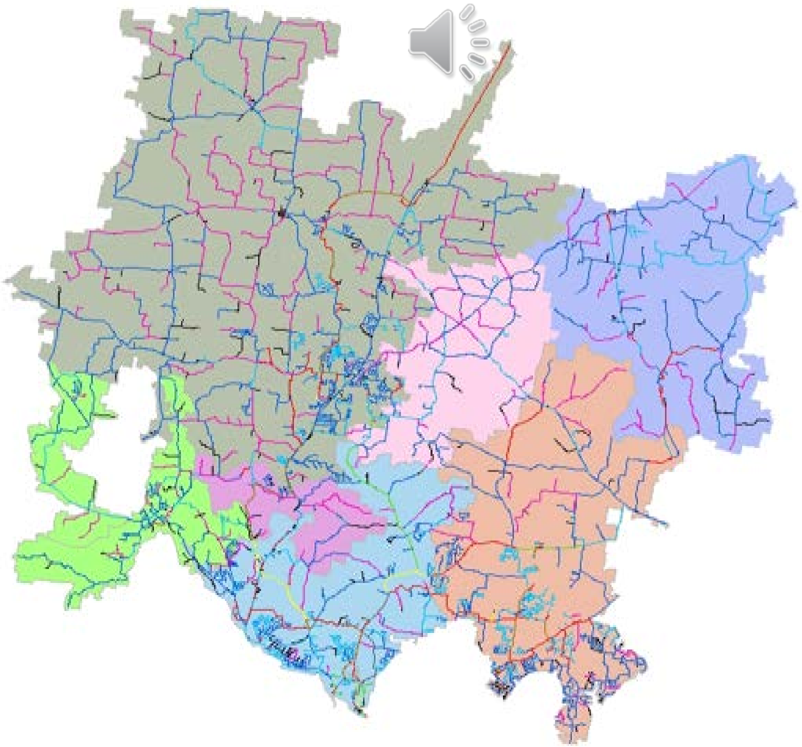
Pressure Reducing Valve (PRV) installed on a residential customer service line

A. How Pressure Levels Vary in Water Systems

Pressure zones in water distribution systems

How are variations in pressure levels managed in water systems?

Water systems are broken into pressure zones reflecting different elevations and hydraulic grades



Water system pressure zones color-coded on a system map

Some zones cover a large area, others a small area

A. How Pressure Levels Vary in Water Systems

High pressure in your water distribution system – **a checklist**

How many of the below questions are a “yes” answer for your utility?

1. Do you have sections of the distribution system over 150 psi?
2. Do any of the above areas experience frequent leak events?
3. Do any of the above areas experience frequent water main breaks?

A. How Pressure Levels Vary in Water Systems: KNOWLEDGE CHECK

What is the reason why pressure levels vary in water systems?

a. Some piping materials can only withstand low pressure
b. Some customers request different pressure levels
c. Ground elevations vary
d. Regulations stipulate that water pressure should vary

A. How Pressure Levels Vary in Water Systems: **KNOWLEDGE CHECK**

Which of the below pressure levels would prompt you to investigate whether pressure impacts might cause high leakage in your water distribution system?

a. 35 psi

b. 80 psi

c. 175 psi

d. 20 psi

A. How Pressure Levels Vary in Water Systems: KNOWLEDGE CHECK

What is the general approach that many water utilities have historically employed to manage pressures?

a. Acoustic leak detection
b. Pressure zones
c. District Metered Areas (DMA)

B. The Impacts of Excessive Pressure

THE PRESSURE – LEAKAGE RELATIONSHIP

- *Leakage flows vary with the pressure inside the pipeline*
- *Let's look at some photos of a leak that demonstrate this*

B. The Impacts of Excessive Pressure

LEAK UNDER LOW PRESSURE

Pipeline is valved mostly closed and under little pressure

Water from a crack in the pipe is barely visible

B. The Impacts of Excessive Pressure

LEAK UNDER MODERATE PRESSURE

Partially opening a valve restores moderate pressure in the pipeline

Water sprays from the pipeline and the crack in the pipe is clearly visible

B. The Impacts of Excessive Pressure

LEAK UNDER HIGH PRESSURE

Fully opening the pipeline valves restores full pressure

Water sprays at high velocity from the crack, revealing a much higher leakage flowrate at high pressure

B. The Impacts of Excessive Pressure

High pressure: potential for significant damage during water main breaks

High pressure cannot be avoided in some cases, but utilities should be aware of pressure levels and manage them responsibly

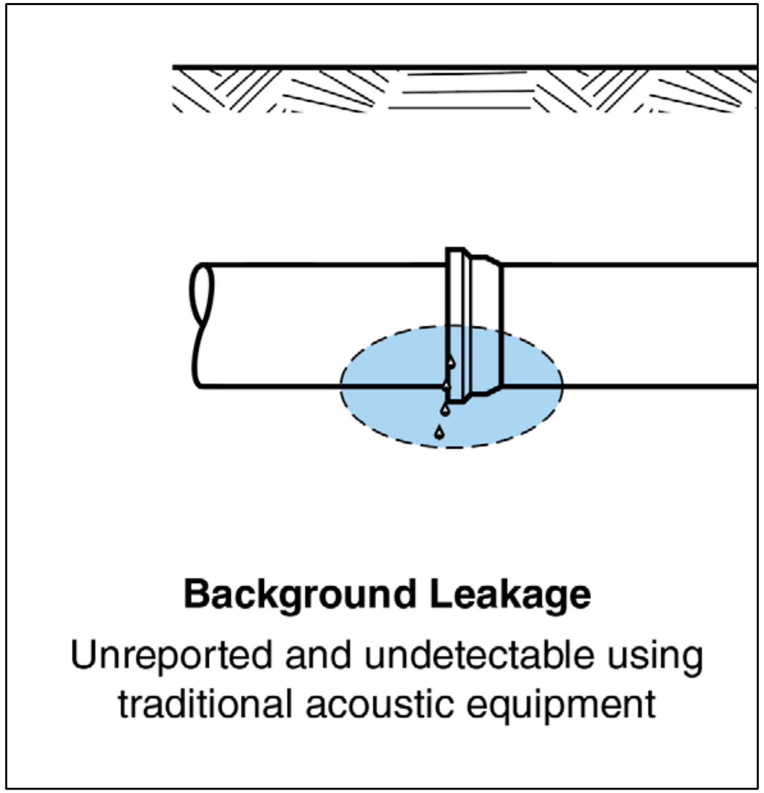
Water leaving a main break under high pressure sprays high into the air and can cause much damage
Photo source: Water World

B. The Impacts of Excessive Pressure

Remember Background Leakage?

I. Background Leakage

- Weeps and seeps at joints and fittings that are **not visible** and **not detectable by** acoustic leak detection equipment
- Very low flow events
- Not cost-effective to excavate to repair
- ***Sensitive to changes in pressure***



Pipeline graphic from the AWWA M36 Manual

High background leakage can be economically controlled by improved pressure management!

B. The Impacts of Excessive Pressure – KNOWLEDGE CHECK

True or False: background leakage is <u>not</u> very sensitive to water pressure levels in the distribution system?

True

False

C. Pressure Management Overview

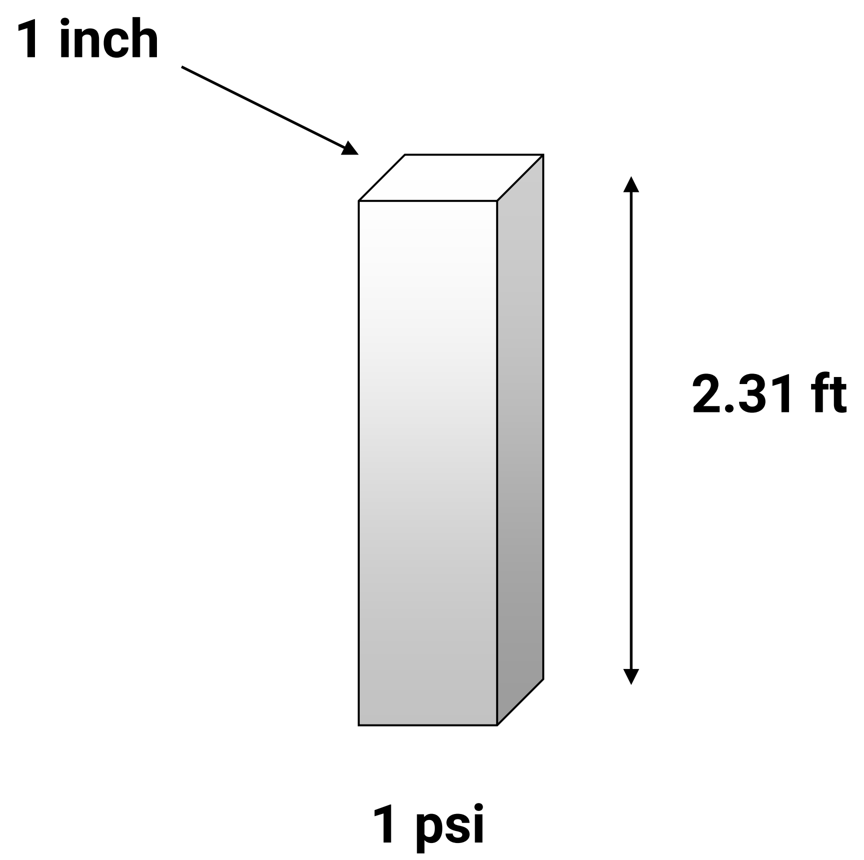
- Pressure Management is a method to reduce leakage and slow water main breaks by moderating ***excessive*** pressure.
- This is carried out in two primary ways:
  - Selective pressure reduction
  - Prevention and control of pressure transients (spikes)

Pressure Reducing Valves for pressure management in Halifax, Nova Scotia, Canada

C. Pressure Management Overview

Water pressure basics

- A water column with a height of 2.31 feet exerts a pressure of 1 psi at the base of the column
- Each foot of water = 0.43 psi
- This is true regardless of how wide the water vessel is or how much water it contains
- Pressure is based upon the height of water only!

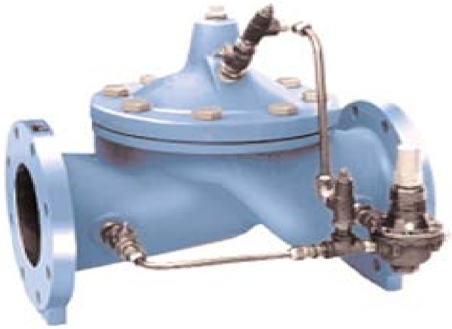


C. Pressure Management Overview

Basic pressure reduction: slightly lower the “full” level on a water storage tank

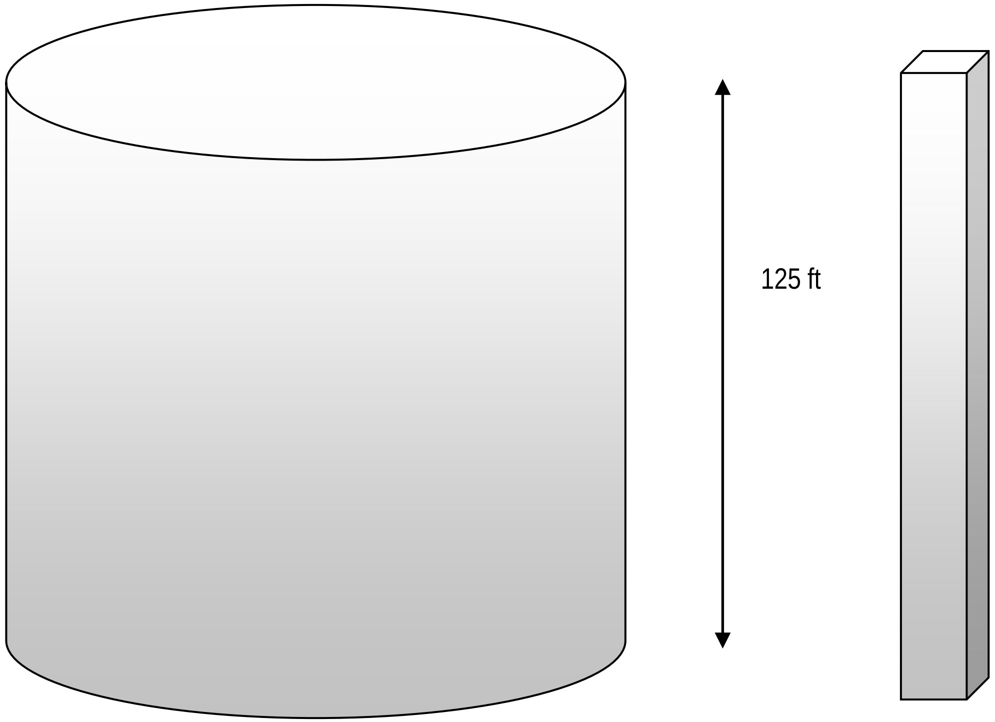
1. Scenario: area served by a tank with high pressure (over 100 psi) with high leakage or frequent main breaks
2. Reduce the high tank level setting at the pumps serving the tank or adjust an altitude valve that controls the water level (if one exists). Target level reduction could be 2-5 feet.
3. Lower the high tank level setting one foot and test for several days to ensure no problems occur. Continue reductions and monitor for problems. Repeat until target reduction is met.
4. Ensure reliable water supply is maintained. Monitor for long-term reduction in leakage/main breaks.

Water Storage Tank


Altitude Valve controls tank level

C. Pressure Management Overview – **KNOWLEDGE CHECK**

What is the pressure at the bottom of the tank shown below? (select your answer from the list)



a. 288.7 psi

b. 125.0 psi

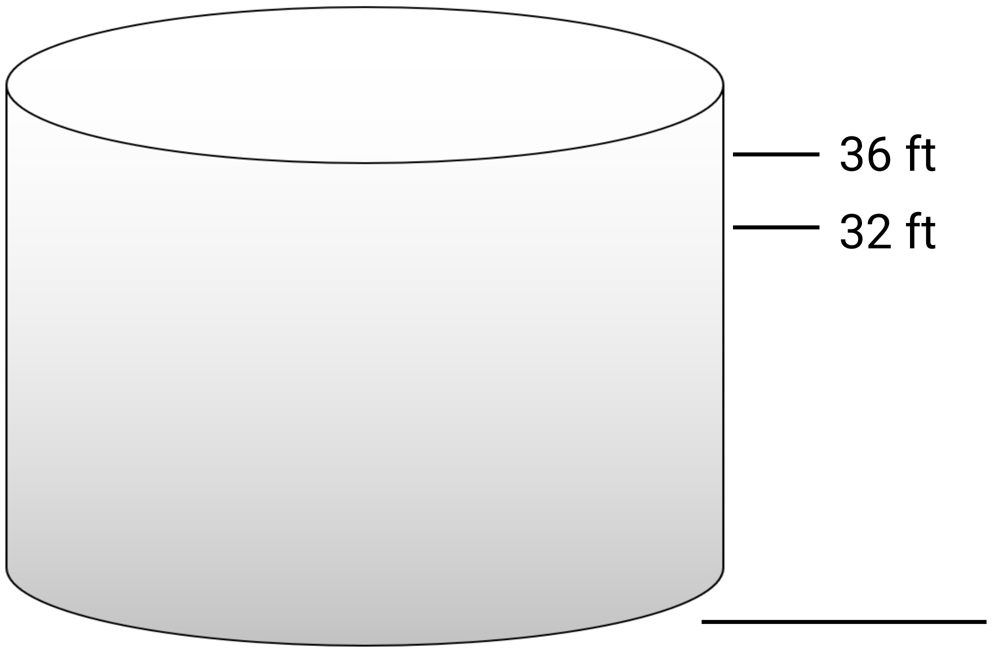
c. 54.1 psi

d. 541.0 psi

C. Pressure Management Overview – **KNOWLEDGE CHECK**

Calculate the reduction in pressure at the base of a 40-foot tall tank if the high tank level setting is reduced from 36 feet to 32 feet.

(select your answer from the list)



a. 1.72 psi

b. 4.0 psi

c. 9.24 psi

C. Pressure Management Overview

Pressure control using ***Pressure Reducing Valves (PRV)***

- PRV's are used in many water distribution systems worldwide
- Basic PRV function: reduce the incoming inlet pressure of water to a desired lower downstream or outlet pressure
- The outlet pressure level can be fixed at a certain level, or vary with the changing flowrate of water
- Fixed outlet pressure is most common, but variable outlet pressure control, or **Flow Modulated Control**, offers many advantages

Pressure Reducing Valve (PRV)

PRVs can be used for pressure reduction to reduce leakage and slow water main breaks!

C. Pressure Management Overview

Pressure reduction using Pressure Reducing Valves (PRV)

A reduction in the outlet pressure results in a reduction of minimum night flow by reducing background leakage

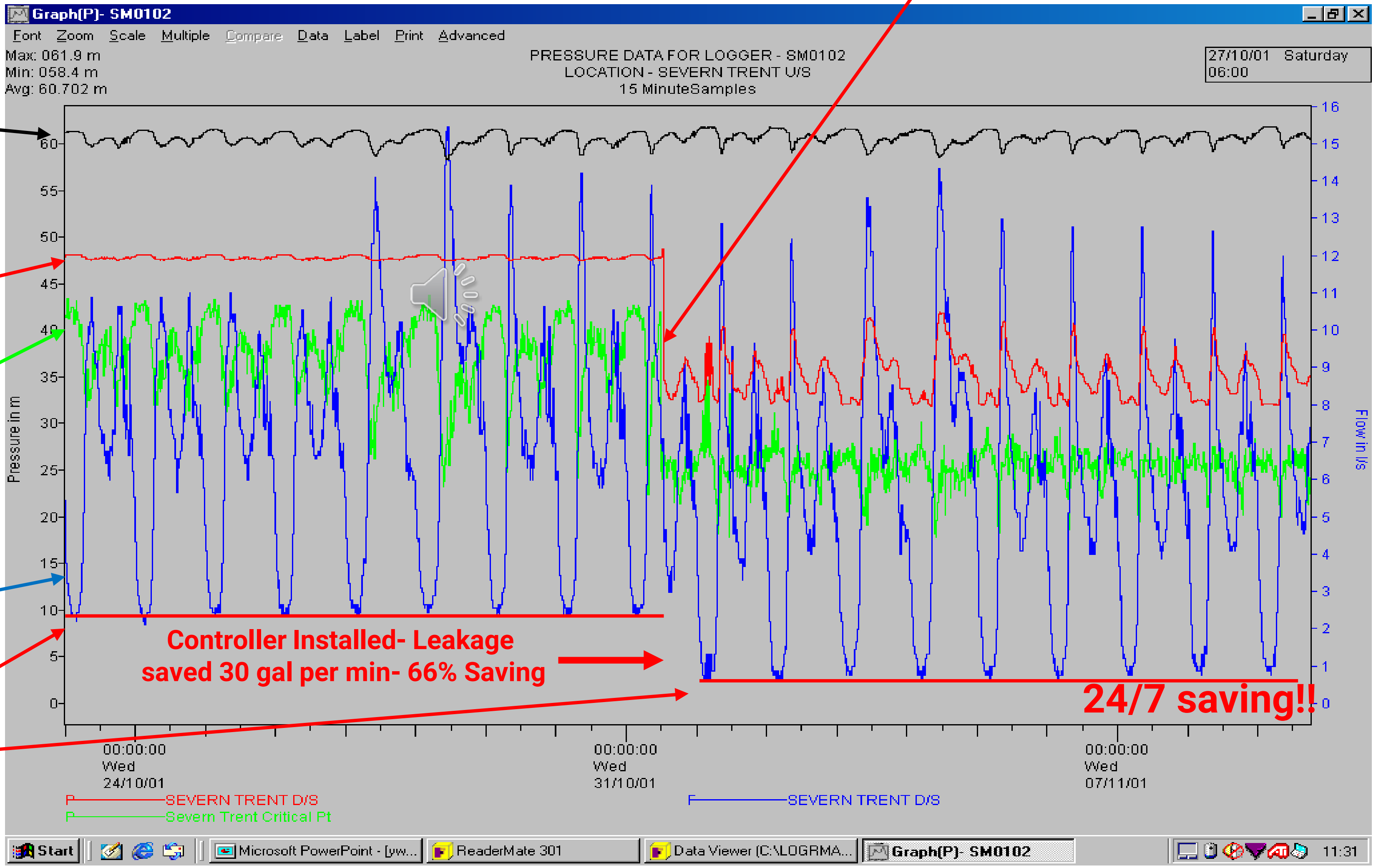
PRV Inlet Pressure

PRV Outlet Pressure

Critical Point Pressure

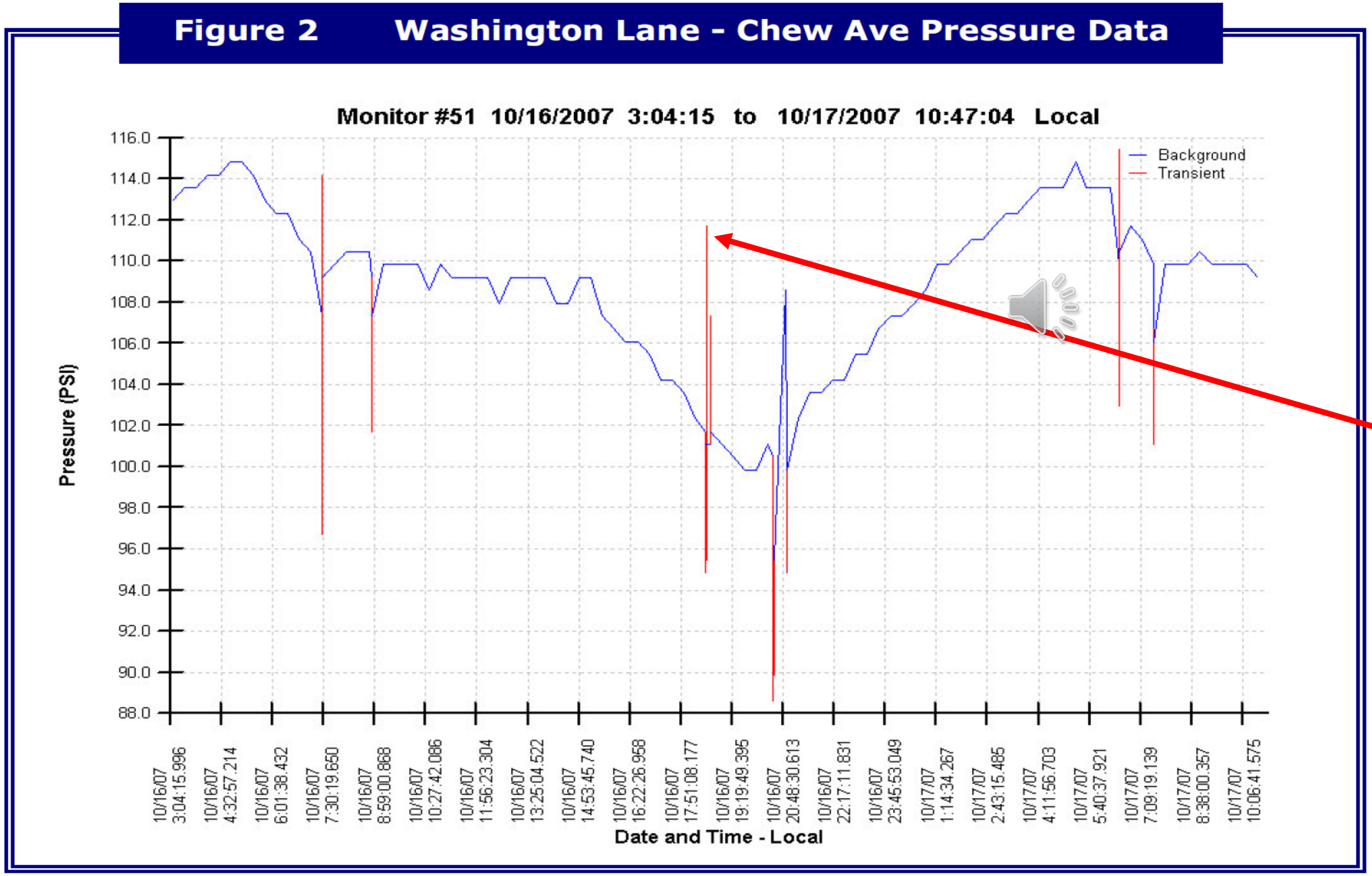
Flow

Minimum Night Flowrate reduction



C. Pressure Management Overview

Pressure control of transients (pressure spikes)



High resolution pressure data logger connected to tap in water main

Red lines reveal very brief, but modest, pressure surges (transients) and drops in piping supplying a DMA. Various controls exist to inhibit transients.

C. Pressure Management Overview: KNOWLEDGE CHECK

Which of the below statements is true for the "Critical Point" in a District Metered Area?

a. It is the location of highest pressure in the DMA

b. It is the location representing the average pressure in the DMA

c. It is the location of the lowest pressure in the DMA, or the location of the greatest head loss in the DMA

C. Pressure Management Overview – KNOWLEDGE CHECK

True or False: pressure transients are very fast acting events that can cause dramatic increases, or surges, in pressure, and significant pressure drops

True

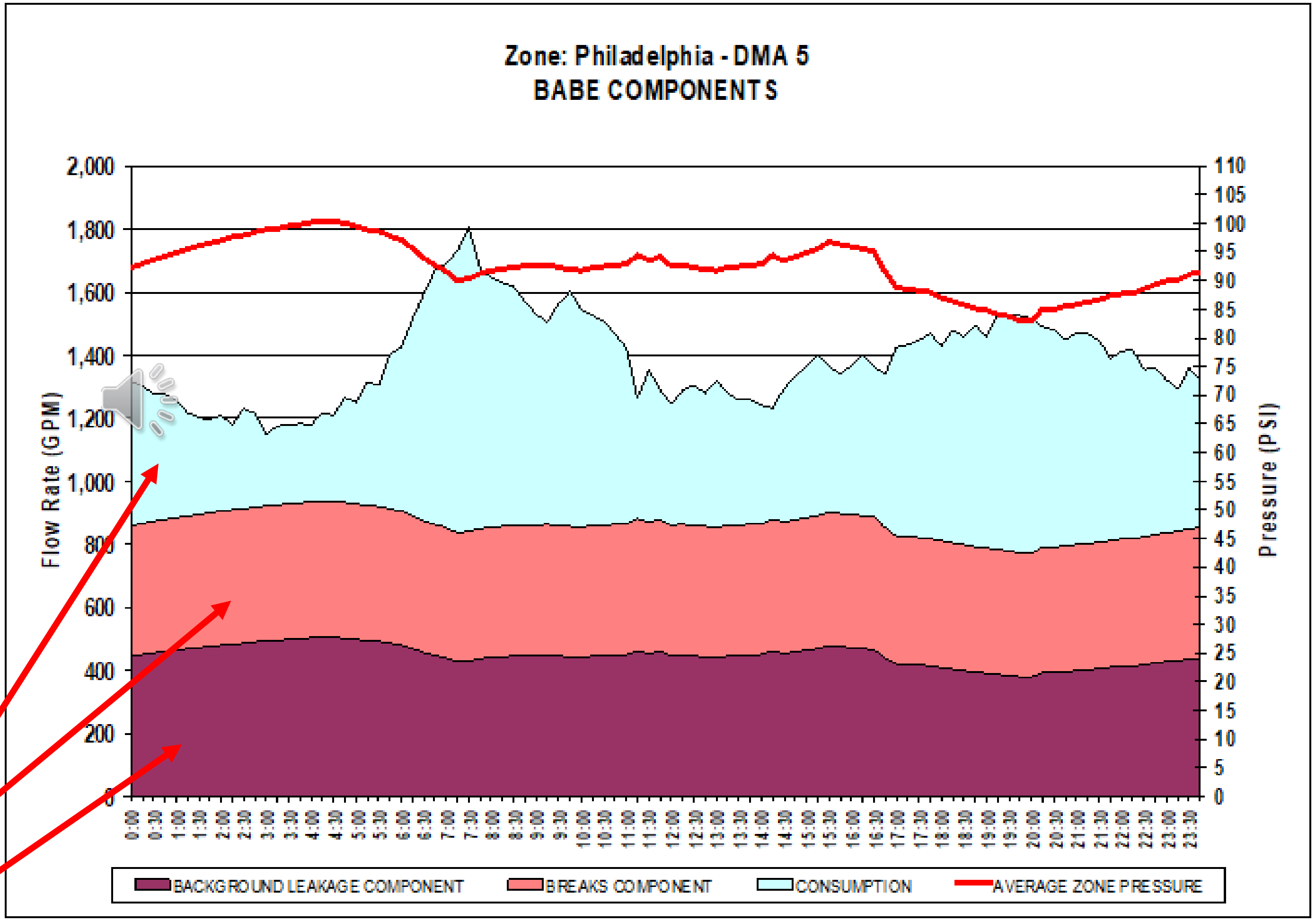
False

C. Pressure Management Overview

Case Study: Philadelphia's DMA5

Philadelphia's District Metered Area 5 (Conditions prior to DMA installation)

- Flow measurements found very High leakage existed: **540 gal/connection/day**
- High unreported leakage existed despite regular leak detection surveys
- High background leakage also existed and confirmed poor infrastructure condition
- Pressure management was determined to be a feasible strategy to manage background leakage



Customer consumption

Unreported leakage

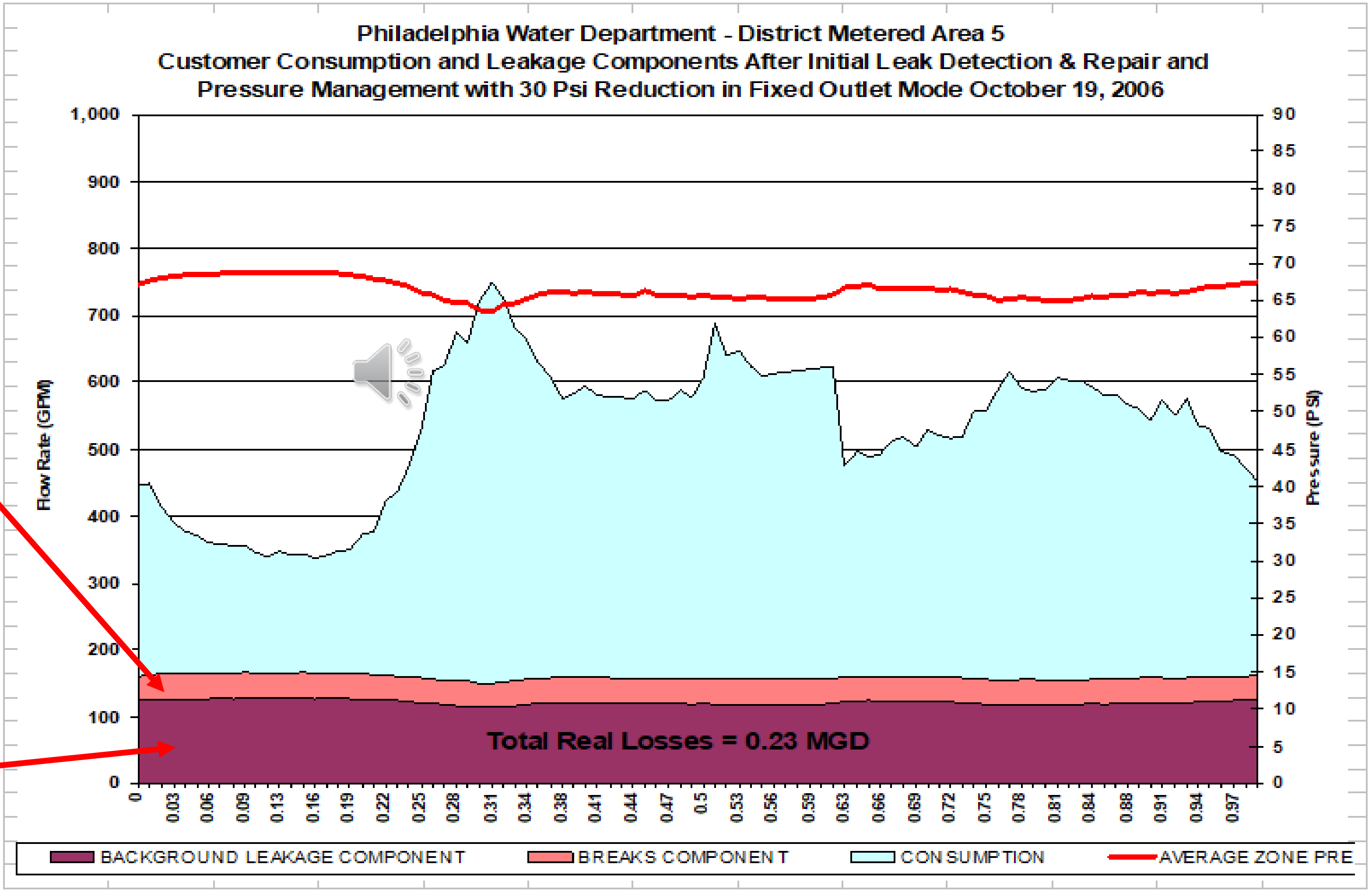
Background leakage

Graph of initial flow and pressure measurements
Source: Water Research Foundation Project 2928

C. Pressure Management Overview

DMA5 – Flow profile after Initial DMA5 Implementation

- Large volume of Unreported Leakage was removed by traditional leak survey and repair
- High background leakage was modestly reduced after initial *fixed outlet* pressure reduction

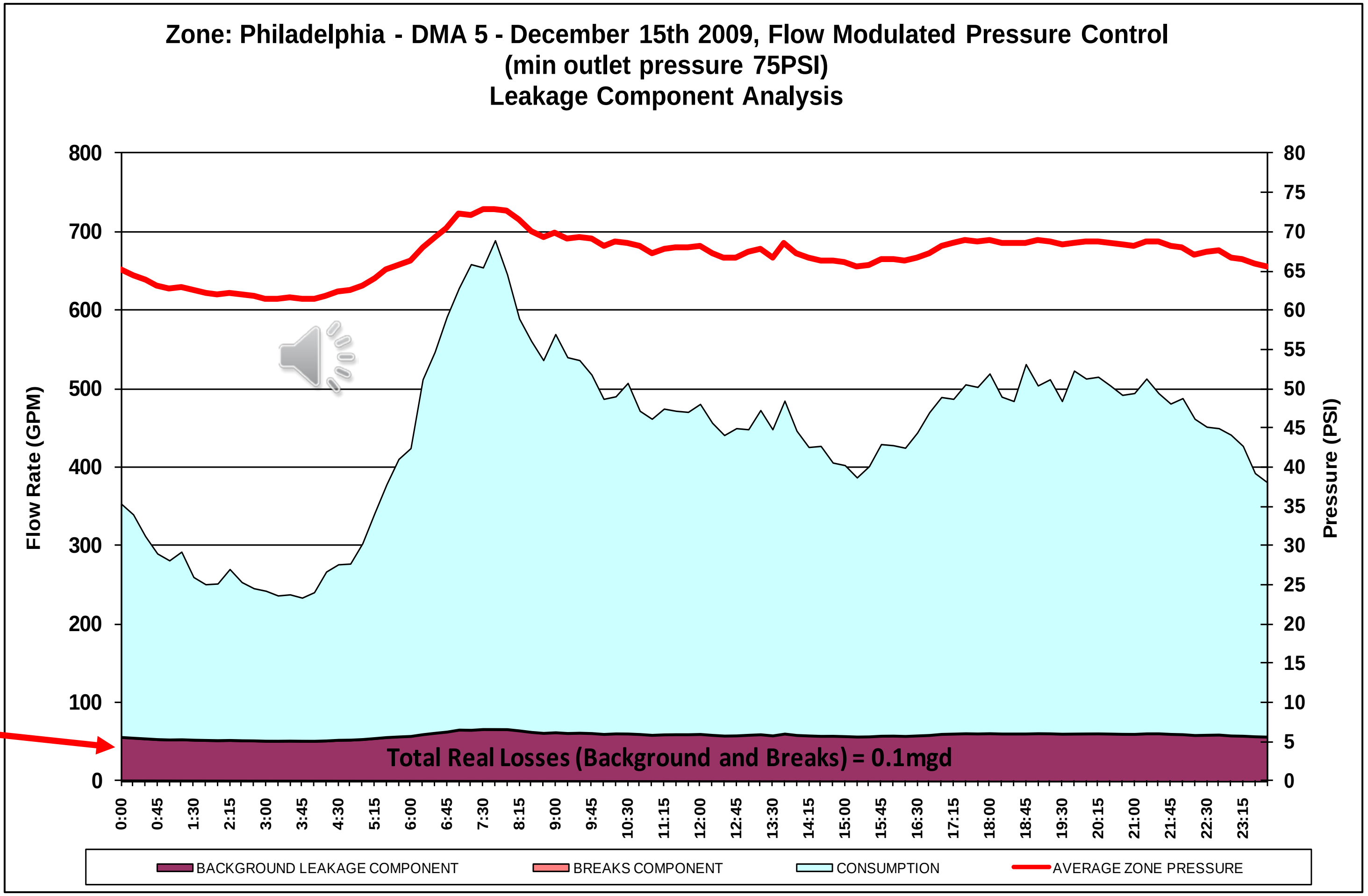


Leakage reductions after leak detection & initial pressure management
Source: Water Research Foundation Project 2928

C. Pressure Management Overview

DMA5 – Flow Profile after leak detection, water main replacement & optimized pressure control

- By the close of the project, *flow modulated* pressure control was implemented and DMA5 had reached the optimized state
- Unreported leakage was almost entirely removed
- Only minimal background leakage remained
- Real losses = **44 gal/conn/day, with an ILI of 2.5**



Final leakage reductions after all leakage activities were implemented
Source: Water Research Foundation Project 2928

C. Pressure Management Overview

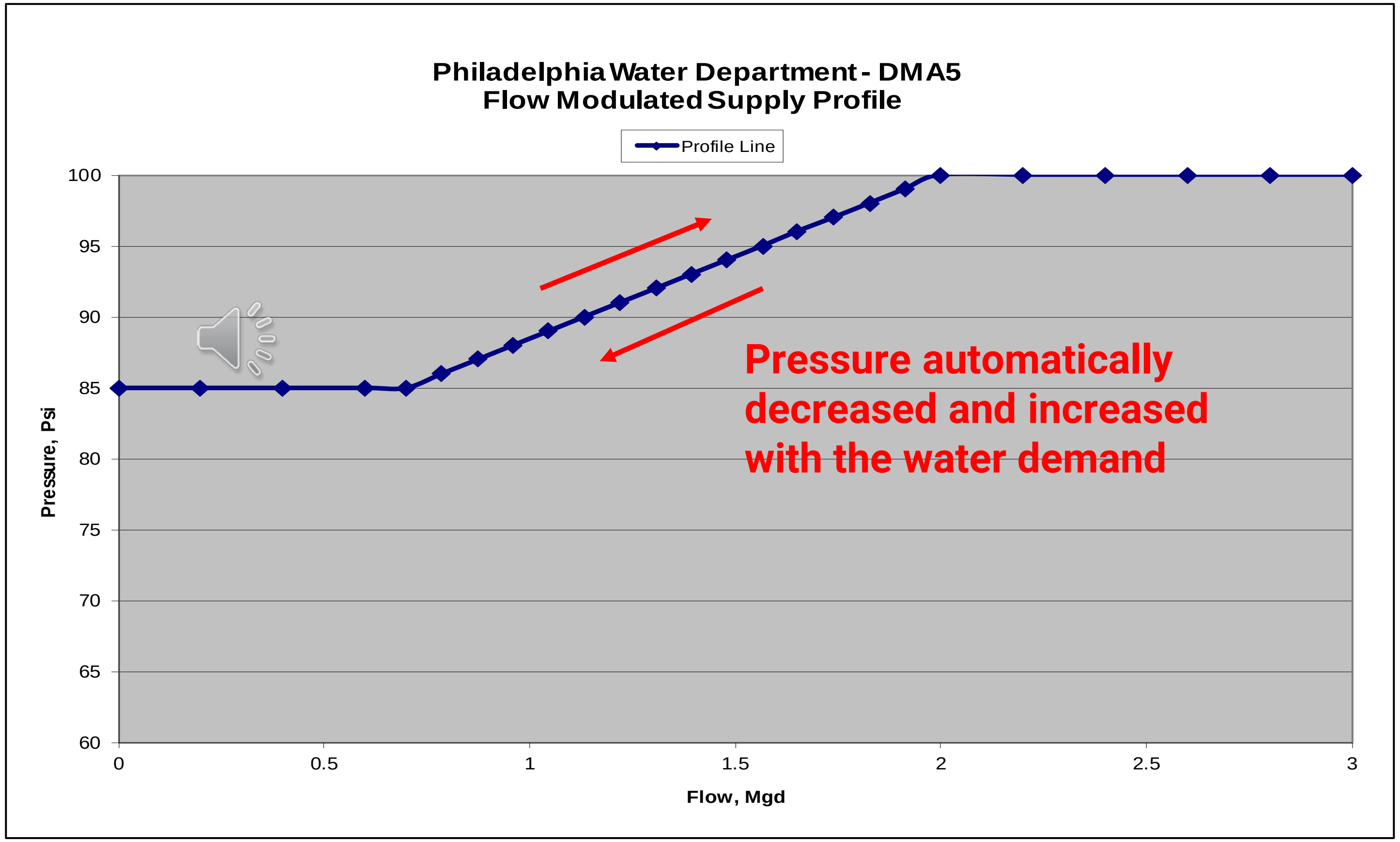
Philadelphia's DMA5 Flow Modulated Pressure Management Scheme

Former Supply Scheme

- Pressure Range: 108 - 150 Psi; high pressure occurred at night when customer demand was low

Improved Supply Scheme

- Supply Pressure range 85 – 100 Psi; low pressure occurs at night when customer demand is low
- Removing the excess pressure cuts background leakage
- Pressure transients are inhibited
- Long-term: water main break reduction



Graph of modulated supply profile that lowers or raises pressure with change in water demand
Source: Water Research Foundation Project 2928

Module 3 Summary

Water pressure varies due to ground elevation and many systems have pressure greater than 100 psi

High pressure of more than 100 psi can result in damaging water main breaks and high loss volumes from background leakage

Excessive pressures can be better controlled by modest pressure reduction from modified tank levels, PRVs, or transient controls.

There is one more module to discuss: how to keep your leakage control efforts going

MODULE 4

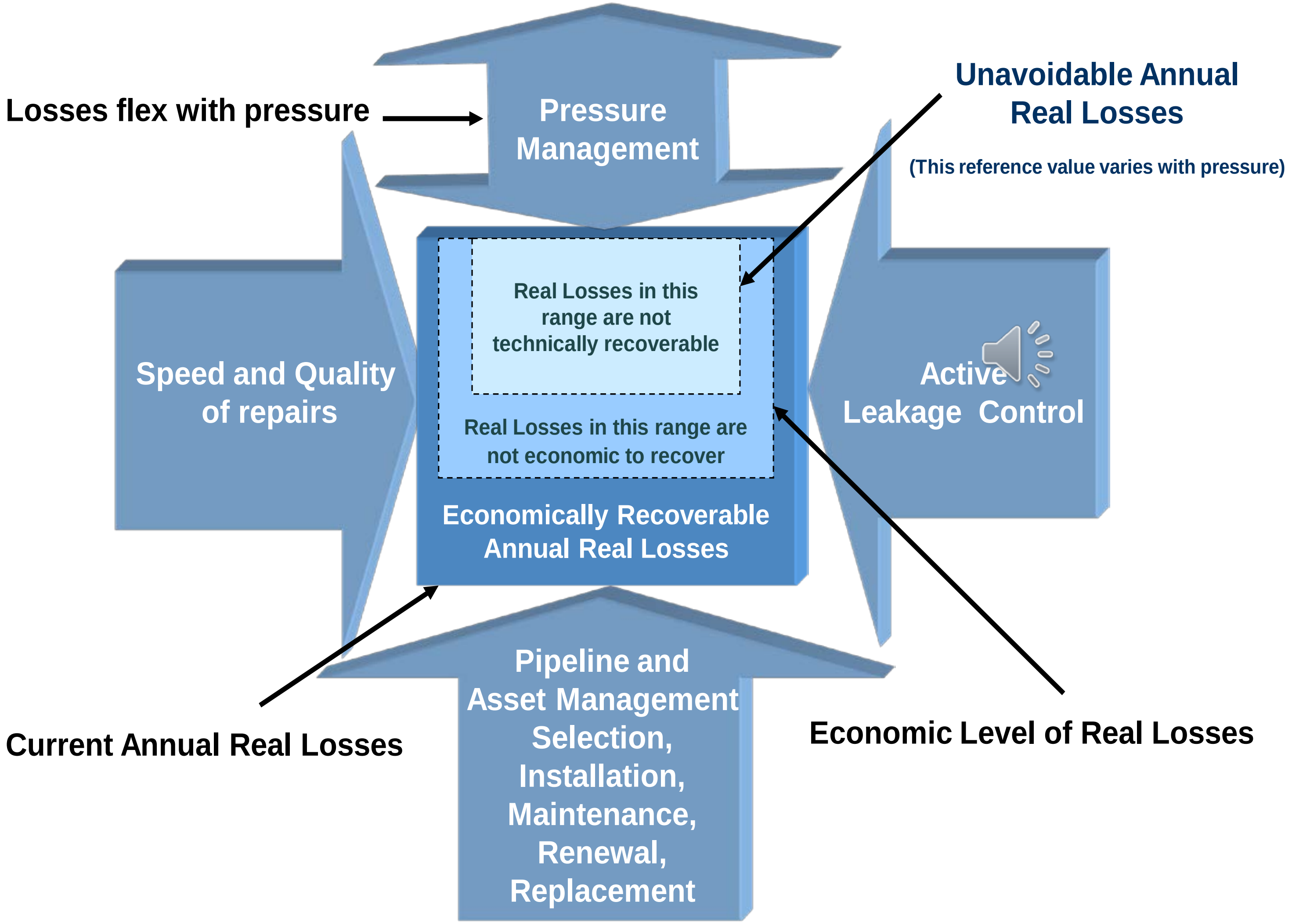
Keeping Your Leakage Control Efforts Going

Learning Objectives

As a result of this module participants should be able to:

1. Identify the Four Pillars of Leakage Management
2. List effective leakage controls that will keep leakage contained
3. Prioritize leakage controls for the long haul

A. Steps to Sustain the Leakage and Pressure Management Program



Four Pillars of Leakage Management

- Active Leakage Control
- Speed & quality of repairs
- Pressure management
- Pipeline asset management

A. Steps to Sustain the Leakage & Pressure Management Program

If you halt your leakage control program, leakage will rise!

Steps to sustain the program

- Conduct leak routinely (every 1-5 years) or as guided by DMA data
- Consider using flow measurement in DMAs to alert high night flows suggesting new leakage
- Conduct quality leak repairs – avoid “re-work”
- Customer service line leaks: how many occur in your system? Are customers responsible for repairs? Are they repaired quickly?

Keep funds for leakage control in your budget most years!

Temporary “broomstick” repair of a blown ferrule

Source: Municipal Water & Sewer Magazine

A. Steps to Sustain the Leakage & Pressure Management Program

Pressure Management and Pipeline Renewal

- Pressure Management
  - Get to know the pressure levels within your system
  - Can you install pressure sensors at key locations?
  - Consider pressure reduction to reduce leakage
- Pipeline Renewal
  - Keep a good inventory of your piping
  - Keep good records of maintenance work conducted on the system
  - Renew (rehabilitate or replace) piping before it reaches the end of its service life

High pressure water at break site

Replacement ductile iron pipe ready for installation

A. Steps to Sustain the Leakage & Pressure Management Program

	Water Distribution System Failure Tracking for:	*Example Water Authority*	
	Year:	2021	
		Unique ID# for failure or work order	
Minimum Required Information	Failure Event Type	*Reported - from complaints*	
		Unreported - from proactive leak detection	Reported
	Network Category of Failure	*Distribution Systems*	
		Transmission System	Distribution
	General Location of Failure Event	*For Example - Street Intersection*	2208 S. Bent Lane- Aston
	Size Information	*Diameter of Pipe at Failure Location, inches*	6
	Failure Event Reported	*Date and Time*	1/5/18 7:15 AM
	Failure Event Pinpointed	*Date and Time*	1/5/18 9:54 AM
	Failure Event Contained/Valved-off/Repaired	*Date and Time*	1/5/18 12:30 PM
	Failure event duration, days		0.22
Additional Information for Reliable Leakage Component Analysis	Detailed Failure Event Information	*Failure Event was reported/detected by:*	Customer
		Nature of failure	Circumferential Crack
		Piping Material at location of failure	Cast Iron
		Year of pipe installation at failure point	1955
		Current Year	2021
		Age of piping at location of failure, years	66
		Average Pressure at Failure Location, Psi	62
		Suspected cause of failure	Thermal effects (cold, heat)
	Detailed Location Description for Failure	*Street Address*	
		Nearest House Number	
		GIS Coordinates (X)	
		GIS Coordinates (Y)	
	Additional Failure Event Information	*Soil condition at location of failure*	
		How was failure repaired?	Repair Clamp
		Estimated Cost to repair failure (labor/materials/equipment/restoration of excavation and pavements)	
		Comments	Pipe is cement lined
		Estimated Leak Flow Rate at 70 psi pressure (using AWWA M36 recommended flow rates), gpm; or utility-specific estimate	111
		Estimated Leak Flow Rate at pressure of failure event, gpm	104.5

Example pipe failure documentation spreadsheet

Pipeline Failure Documentation

- Data capture is essential to understand the occurrence of leaks and breaks and plan controls
  - Obtain data describing the failure including key dates
  - Log the suspected failure cause
  - Note the method of repair
  - Describe environmental conditions
  - Document damage/impacts
  - ***Take photos of the failed piping and surroundings!***

A. Steps to Sustain the Leakage & Pressure Management Program

CALCULATION OF ECONOMIC INTERVENTION FREQUENCY FOR PROACTIVE LEAK DETECTION			
	System Characteristics		
	Total Length of Mains	2,741.0	miles
	Number of Service Connections	535,924	service connections
	Service Connection Density	195.5	conn./mile main
	Average System Pressure	65.0	PSI
	Water Balance Results		
TBL	Current Annual Background Leakage	11,507.14	MG/Yr
CRL	Real Losses from Current Reported Leakage	1,820.00	MG/Yr
UL	Unreported Failures Identified Through Existing Proactive Leak Detection Program	399.41	MG/Yr
	Hidden Failures/Unreported Failures not Identified or Captured by Current Leakage Management Policy	11,608.65	MG/Yr
CARL	Current Annual Real Losses	25,335.20	MG/Yr
UARL	Unavoidable Annual Real Losses	2,475.76	MG/Yr
	Infrastructure Leakage Index (ILI) [CARL/UARL]	10.2	
	Variable Cost of Real Losses		
CV	Variable Production cost (applied to Real Losses):	0.41	$/per kgal
		413.99	$/MG
CI	Cost of comprehensive leak detection survey (excluding leak repair cost)	508.00	$/per mile
		1,392,428	$/for entire system
RR	Average Rate of Rise of Unreported Leakage	0.82	kgal/mile of mains/day in a year
		2.25	MG/day in a year
	CI/CV	1227.1	kgal/mile
EIF	Economic Intervention Frequency [0.789 * (CI/CV)/RR] ^0.5	34.4	months
		1,045.2	days
	Economic Intervention Frequency - Average Leak Run Time	522.6	days
	Economic Percentage of System to be Surveyed per Year	35	%
ABI	Average Annual Budget for Intervention (Proactive Leak Detection)	486,279	$/year
EUL	Economic Unreported Real Losses	1,174,615	kgal/year
		1,174.6	MG/year
	Economic Infrastructure Leakage Index (ILI)	6.0	
PRL	Potentially Recoverable Leakage (CARL-CRL-EUL-TBL-UL)	10,434.0	MG/year

WaterRF 4372: Real Loss Component Analysis: A Tool for Economic Water Loss Control

- Leakage Component Analysis (LCA)
  - A modelling method and software tool that uses data on leak occurrences as inputs
  - The model identifies the amount of leakage that is economic to recover and how often to conduct leak detection
  - The Water Research Foundation (WRF) and EPA created a free software tool that conducts the LCA, available at:
  - https://www.waterrf.org/research/projects/water-audits-and-real-loss-component-analysis

Economic Intervention Frequency worksheet of the LCA tool – defines how often to conduct acoustic leak detection

A. Steps to Sustain the Leakage & Pressure Management Program – KNOWLEDGE CHECK

Match the "pillar" in the bubble on the left from the "Four Pillars of Leakage Management" diagram with the activities under it in the bubble on the right

a. Speed & Quality of Repairs

b. Pressure Management

c. Active Leakage Control

d. Pipeline & Asset Management

___ Replacement piping before it reaches its end of life

___ Measuring flow in a District Metered Area (DMA)

___ Operating tank levels at a lower level

___ Initiating a customer service line warranty program to assist customers in addressing leaking services lines

A. Steps to Sustain the Leakage & Pressure Management Program – KNOWLEDGE CHECK

Match the "pillar" in the bubble on the left from the "Four Pillars of Leakage Management" diagram with the activities under it in the bubble on the right

a. Speed & Quality of Repairs

b. Pressure Management

c. Active Leakage Control

d. Pipeline & Asset Management

_d__ Replacement piping before it reaches its end of life

_c__ Measuring flow in a District Metered Area (DMA)

_b__ Operating tank levels at a lower level

_a__ Initiating a customer service line warranty program to assist customers in addressing leaking services lines

A. Steps to Sustain the Leakage Management Program: KNOWLEDGE CHECK

What does "LCA" stand for (as was presented in this course):

a. Labor Condition Application
b. Leakage Component Analysis
c. Life Cycle Analysis
d. Linear Conversion Algorithm

Module 4 Summary

New leakage is always emerging in water systems; thus, the water utility must work to keep it in check

Leakage and Pressure Management activities should be continuous if leakage is to be contained to reasonable levels

Quality leak repairs are important: a poor repair is just another future leak site

All pipelines eventually reach the end of their service life and should be replaced or rehabilitated

Course 3 Summary

Leakage is inevitable in water distribution systems, but it can be contained in cost-effective ways

Leakage has costs and utilities should put a number to these costs to understand its impact to their financial bottom line

Acoustic leak detection and District Metered Areas represent traditional and newer methods to control leakage

Monitoring and reducing excessive pressure can reduce leakage and extend the life of pipelines

Leak repair and pipeline renewal work are also important activities to keep leakage contained

Course 3

Final Assessment Questions

(See accompanying list)

CONTROLLING NON-REVENUE WATER IN DRINKING WATER UTILITIES – ELXX

Disclaimer

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Course 4 Preview

Customer Metering and Billing Operations for Optimized Revenue Capture

This course covers best practices for accurate metering and billing to ensure a reliable revenue stream, including:

- Tracking customer consumption
- Managing the customer meter population
- Efficient billing operations to maintain the revenue stream

Thank you for completing Course 3
AWWA eLearning

Effective Leakage and Pressure Management