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Under Pressure: the Hidden Threat of High Pressure in Water Systems

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The Role of Pressure

Pressure is our friend!

- Air pressure floats balloons!
- Water pressure makes water flow from fixtures to give us water where and when we need it

Source: www.education.com

Source: YouTube.com

The Role of Pressure

But - - Too much pressure causes problems!

- Balloons can rupture
- Water pipelines can also rupture

Keeping pressure levels in an optimum range is critical to effective operations

Source: friendsofactionpark.co.uk

Source: Water System Optimization

Pressure - Leakage Relationship

- *Leakage flows vary with the pressure inside the pipeline*
- *See the photos of a leak on the next three slides*

Photos & Pressure Management Slides courtesy of Kenneth J. Brothers, Commissioner of Public Works, Niagara Region, Canada & Allan Lambert, ILMSS, UK (2009)

Leak under Low Pressure

Leak under Moderate Pressure

Leak under High Pressure

Pressure in Water Distribution Systems

- Ten States Standards* state that "normal working pressure should be approximately 60-80 pounds per square inch (psi)"
- Many water distribution systems operate under pressure levels that often exceed 100 pounds per square inch (psi)
- Pressure ensures that water is released when needed in a ***controlled*** manner (faucet, hose, etc.)
- Leakage occurs when water is released in an ***uncontrolled*** manner due to a failure in the distribution system piping
- Leakage and ruptures occur due to ***failures*** from pipe deterioration, poor installation, unexpected stresses, and other factors – and influenced by the level of pressure

Source: Golabz

Source: Fox29 TV, Philadelphia

*Water Supply Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers *Recommended Standards for Water Works*

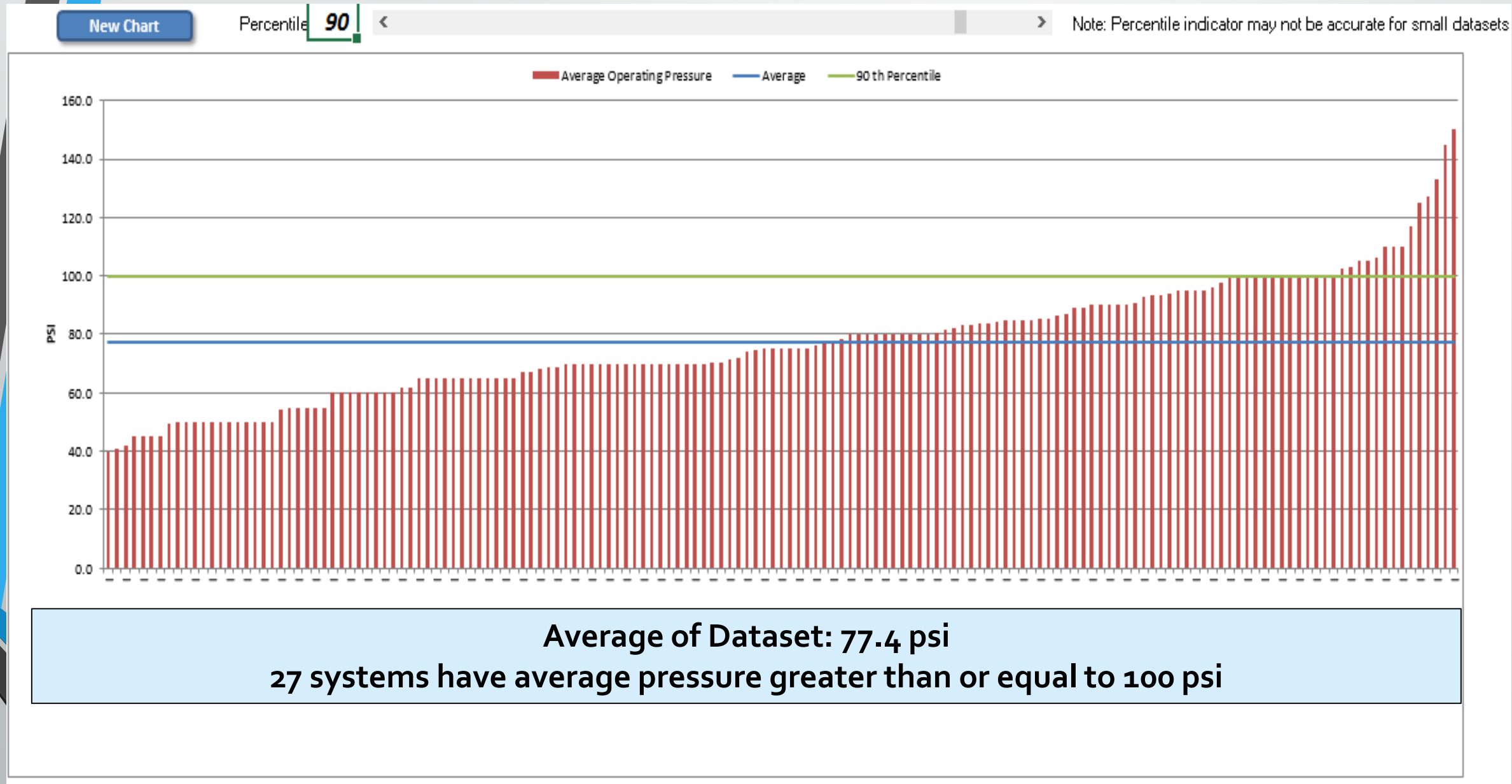
Pressure Levels in Water Utilities

Table· 6-1 ° Assessment· of· average· water· pressure· levels· reported· in· validated·water·audits·in·North·American·water·utilities*¶

Validated· Water· Audit·Data·Source¤	No.· of· Utility· Audits¤	Average· of· All· Pressure· Values·(psi)¤	No.· of· Utilities· With· Pressure·Over· 80·psi¤	Average· Value· for· Those· Systems· With· Average·Pressure·>·80· psi¤
AWWA· WLCC· 2013†¤	26¤	80¤	12¤	98.3¤
Georgia—Large· Systems·2011‡¤	107¤	77¤	53¤	93.7¤
Georgia—Small· Systems·2012‡¤	100¤	72¤	26¤	105.5¤
All·Utilities¤	233¤	76¤	91¤	97.7¤

Source: AWWA M36 Manual: *Water Audits and Loss Control Programs*

Average Operating Pressure in 155 PA Water Utilities



Average of Dataset: 77.4 psi
27 systems have average pressure greater than or equal to 100 psi

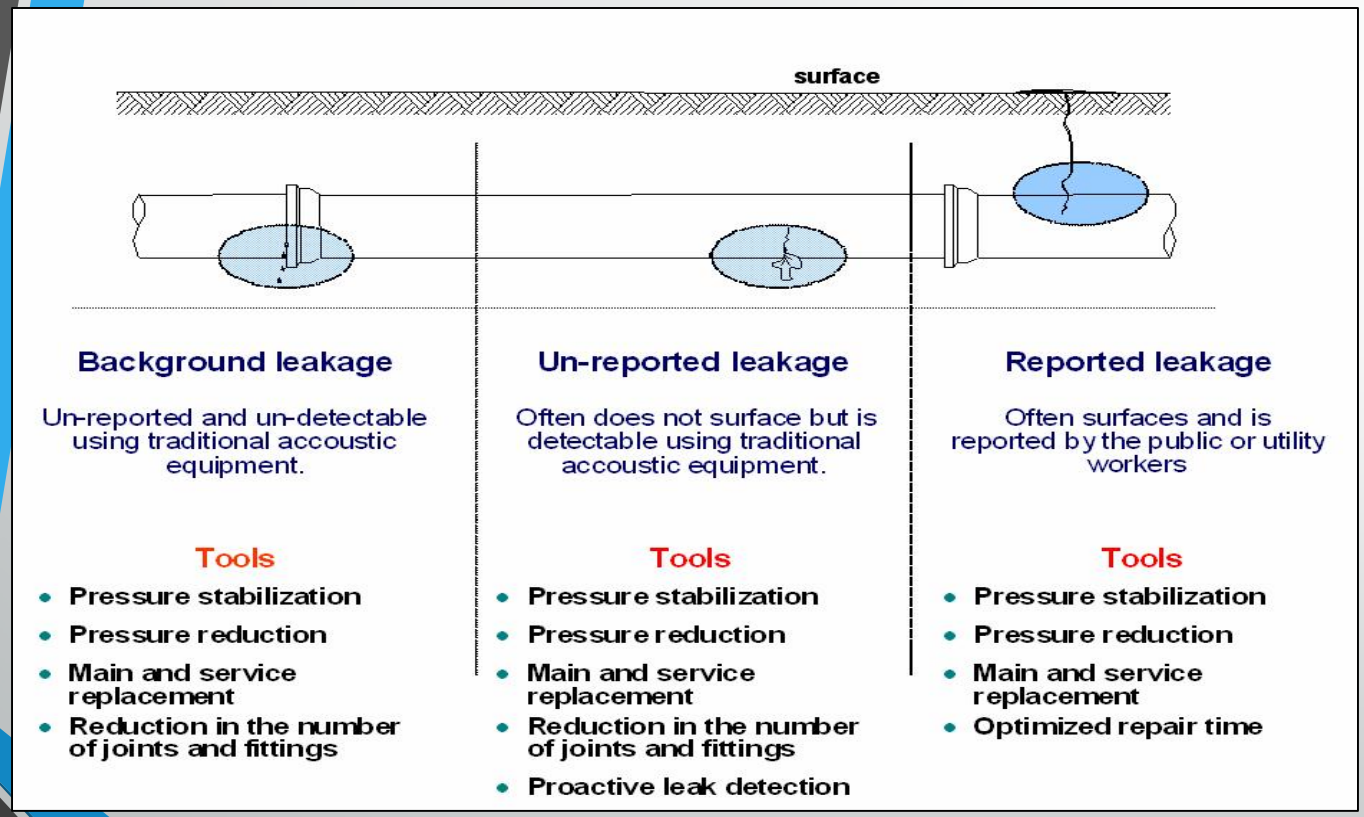
Why Do Utilities Have Excessive Pressure?

- Many systems in hilly terrain are hard-pressed to have system designs that avoid high pressure, but designs should consider the trade-offs
- Providing acceptable pressure at water storage tanks or customer buildings high on a hill can mean high pressure in the pipeline that traverses the valley
- Excessive pressure comes at a cost in energy and can have negative impacts on the distribution system

Source: commons.Wikimedia.org

Failures in Water Distribution Systems

Three Types of Leakage Occurrences



Improved Pressure Management can assist in stemming the occurrence of all types of leakage, but:

- Can be very effective in controlling **background leakage**
- Can inhibit new disruptive ruptures (**reported leakage**)

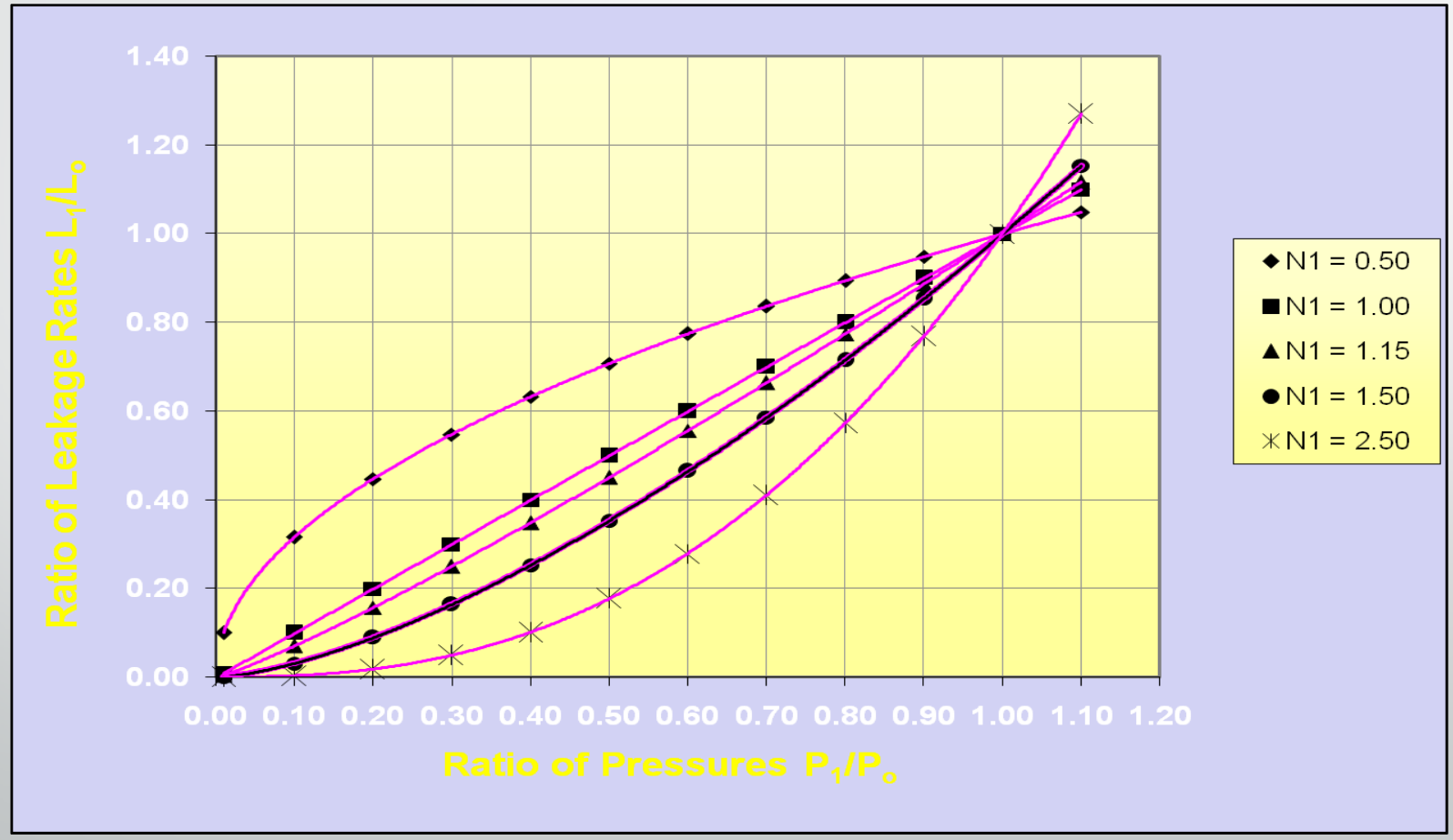
FAVAD Pressure Modelling Concept (Fixed and Variable Area Discharge Paths)

Pressure (P) and Leakage Rate (L): $(P_1/P_0)^{N1} = L_1/L_0$

- Fixed path: characteristic of metallic pipe, where the "hole" of a leak remains a fixed size. N1 = 0.5
- Variable path: characteristic of plastic pipe (pipe split grows with increasing pressure), service leaks, and very poor infrastructure. N1 = 1.5 or higher
- The N1 value for a system can be calculated from data taken during field tests
- The higher the N1 value, the more sensitive the system leakage is to pressure level
- ***Background leakage, and leakage on plastic pipes, are very sensitive to pressure levels, and changing pressure***

Relationships between Pressure (P) and Leakage Rate (L):

$$(P_1/P_0)^{N1} = L_1/L_0$$



Graphic source: IWDC Ltd

Pressure Management in Water Utilities

- "Pressure Management: the practice of managing system pressures to the optimum levels of service, ensuring sufficient and efficient supply to legitimate uses and consumers, while reducing unnecessary or excess pressures, eliminating transients and faulty level controls, all of which cause the distribution system to leak unnecessarily."

  (Source: AWWA M36 Publication, 4th Ed)

- Pressure management keys on better managing "excessive" pressures
- Pressure management schemes must be properly engineered, and address considerations such as:
  - Provision of adequate fire flows
  - Potential reduction in customer consumption/revenue
  - Maintenance of adequate water circulation to preserve water quality

Pressure Reducing Valve used for pressure management installation in Philadelphia

Pressure Management

Pressure Management strives to better manage excessive pressures, and includes:

- transient control
- pressure sustaining or relief
- altitude and level control in tanks and water storage facilities
- implementation of controlled Pressure Management Areas (PMA), often in conjunction with DMAs
- pressure stabilization and reduction

(Source: AWWA M36 Publication, 4th Ed)

Queen Lane Pumping Station in Philadelphia

Pressure Management Benefits

	Applicability to US & Canada
1. Reduction of leak flow rates	Medium
2. Reduction of numbers of new mains breaks – reduces main repair costs	High
3. Reduction of numbers of new service leaks - Reduces service repair costs	Low
4. Reduction of rate of rise of unreported leaks - reduces costs of active leakage control	Low
5. Deferment of infrastructure renewal costs - extends asset life of mains and/or services	High
6. Reduction of some components of consumption	Low
7. Improved customer service fewer interruptions, less damage to plumbing	Low

To make a financial case for pressure management, we need practical methods to predict each of these benefits for individual zones, depending on local circumstances

Source: A Lambert, Ferrara Keynote Address, 2010

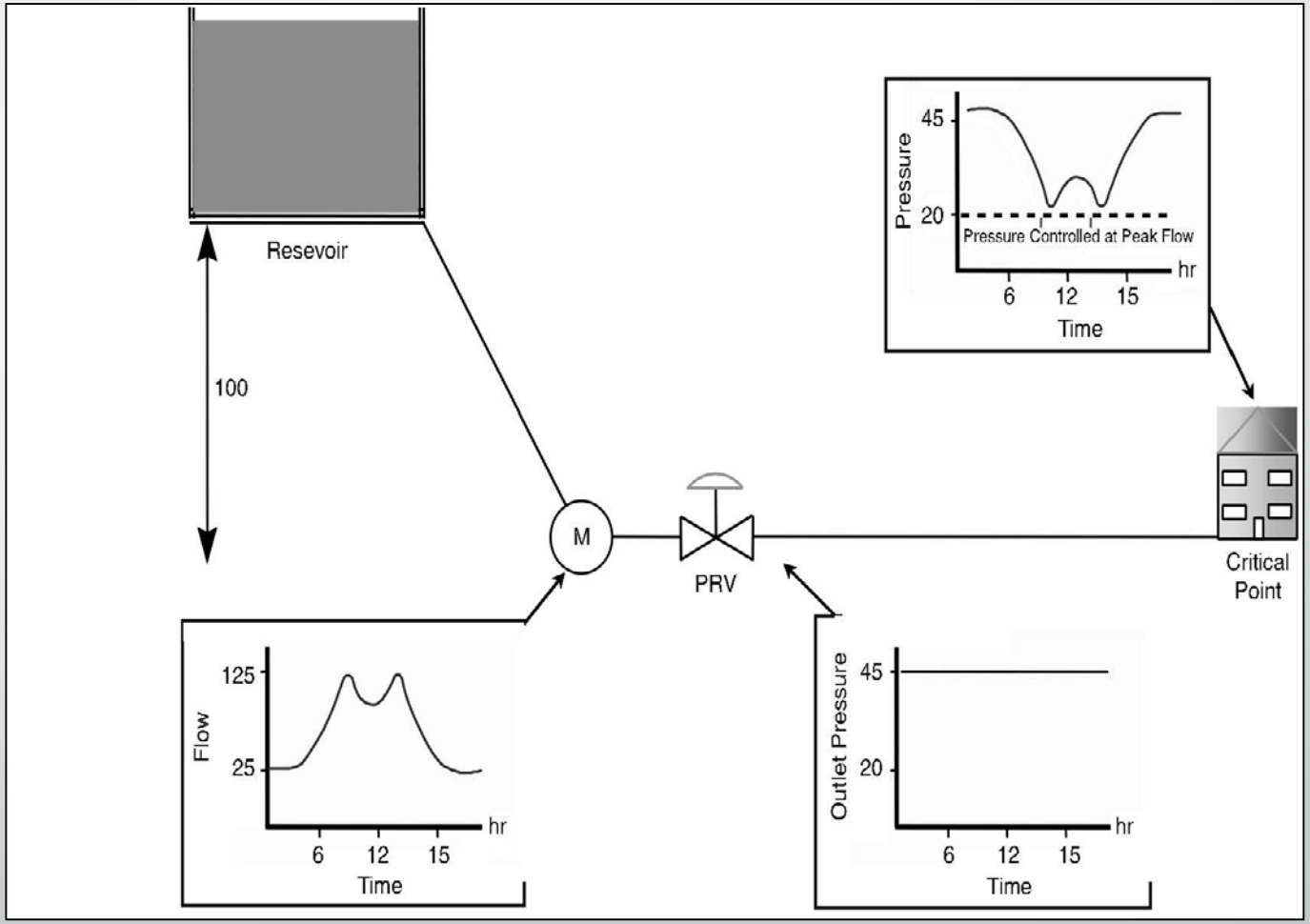
Pressure Management Schemes

Most common: Fixed Outlet Control

A pressure reducing valve reduces the inlet flow to a set outlet pressure and maintains this pressure at the outlet despite pressure changes in the PMA

The *Critical Point* (CP) is the location of the lowest pressure in the PMA due to topography and/or head loss in the grid.

The *Average Zone Point* (AZP) is the location in the PMA that is most representative of average pressure level



Source: AWWA M36 Publication, 4th ed.

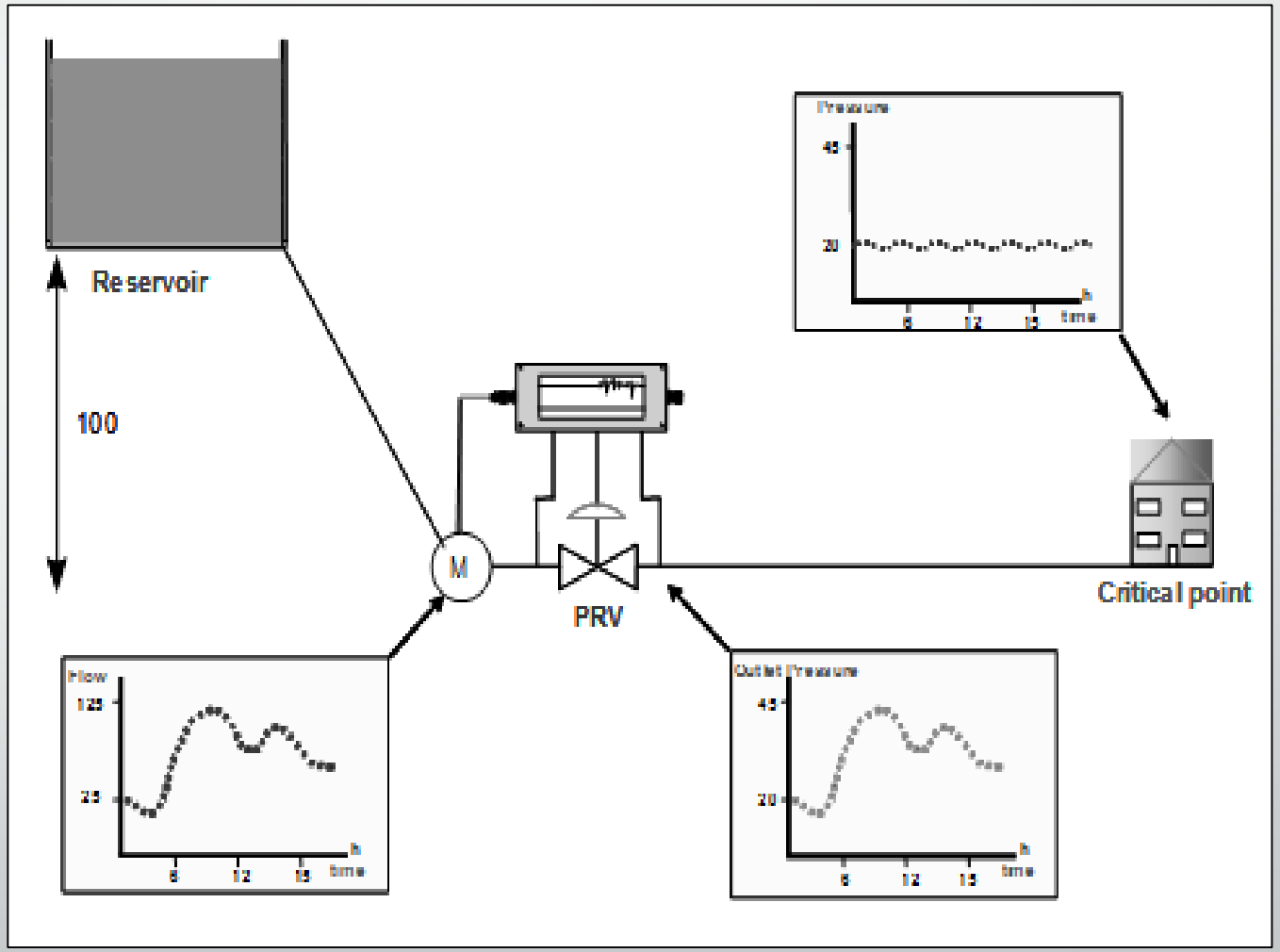
Pressure Management Schemes

A Strong Alternative: Flow Based Dynamic Modulation Control

A controlling device is used in conjunction with the PRV and controls the pilot on the PRV. A range of pressures relative to flow is configured in the controller

The PRV regulates pressure in response to flow changes in the PMA.

Higher pressure is delivered to the PMA when higher flows exist. Pressure is reduced when low flows exist (nighttime for most areas).



Source: AWWA M36 Publication, 4th ed.

District Metered Areas and Pressure Management in Halifax, Nova Scotia, Canada

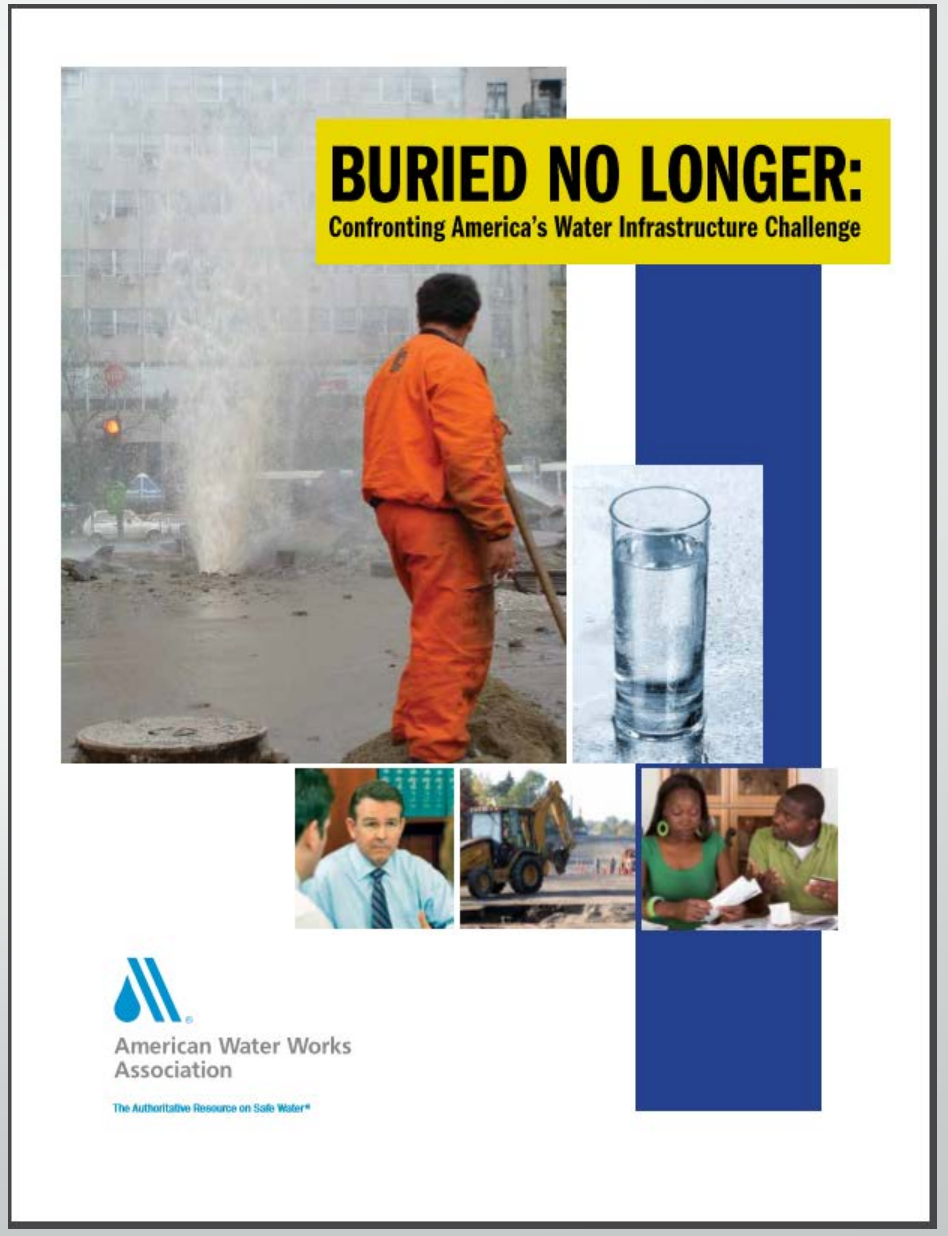
- Halifax operates 75 DMA's with Advanced Pressure Management in 6 areas.
- Managing water loss became a core strategy in the organization's culture
- All DMA control chambers have standard design and instrumentation.
- Pressure Management has allowed Halifax to better manage high pressure at low elevation DMA's near sea level at port.

Photos Source: Halifax Water

The Greatest Benefit of Pressure Management?

Buried Infrastructure Sustainability

- AWWA's "Buried No Longer:" Report (2012) projected infrastructure need of **$1 trillion** over the next 25 years, but - - -
  - Needs are based upon full replacement cost
  - Priorities are determined largely from the rate of water main breaks
  - Main breaks are taken as evidence of deteriorating infrastructure, but - - -
- Many main breaks may be caused by excessive pressure
- Improved pressure management can lessen the need for infrastructure renewal, and do it at a relatively modest cost



What can Water Utilities Do?

- Document water pressure levels in the system
  - SCADA System
  - Hydraulic Model
  - Manual Pressure data gathering (logging fire hydrants)
- Assess areas with pressure over 100 Psi
  - Correlate occurrence of main breaks/leaks
  - Determine background leakage (field tests)
- Seek guidance to implement pressure management in areas of high pressure and high failure rate

Large Pressure Management installation in South Africa
Source: Ronnie McKenzie, WRP Pty Ltd.

Summary

- Adequate water pressure is essential, but excessive pressure is problematic and not well understood
- Many water utilities have high pressure (> 100 Psi) but have not assessed the impact to their system, which include:
  - Higher Leakage
  - High rate of water main breaks
- The technique of Pressure Management has evolved rapidly and offers many advantages in sustaining distribution infrastructure
- Pressure Management can also greatly assist the upkeep of water infrastructure by lessening renewal needs at relatively small cost
- Water utilities should assess the levels of pressure in their system and determine if improved pressure management will provide benefits