Under Pressure: Strategies for Maintaining Distribution System Pressure and Minimizing Public Health Impacts

PNWS AWWA

May 5th, 2011

Boise, ID

Melinda Friedman, P.E.

confluence ENGINEERING GROUP LLC

517 NE 92nd Street, Seattle, WA 98115 ph (206) 527-6832 fx (206) 527-3148 confluence-engineering.com

Pressure is Major Focus of Revised Total Coliform Rule and Distribution Research & Information Collection Agenda

- AIP identified seven research and information collection priority topics
  - Tier one:
    - Cross-connections and backflow of contaminated water
    - Contamination due to storage facility design, operation or maintenance
    - Contamination due to main installation, repair or rehabilitation practices
    - Contaminant intrusion due to pressure conditions and physical gaps in DS infrastructure
  - Tier two:
    - Significance and control of biofilm and microbial growth
    - Nitrification issues that lead to public health effects
    - Accumulation and release of contaminants from DS scales and sediments

DSRICP High Priority Project Areas

1. Survey of Large Drinking Water Utility Distribution Systems
2. Epidemiological Studies of Health Effects Associated with Low or Negative Pressure Events in Distribution Systems
3. Quantitative Microbial Risk Assessment (QMRA) to Evaluate Exposure to Pathogens through Drinking Water Distribution Systems
4. Contaminant Entry from Breaches in Storage Facilities

High Priority Project Areas

5. Estimation of Contaminated Water Volumes and Contaminant Concentrations Introduced Into Distribution Systems Due to Backflow Events from Unprotected Cross-Connections Based on Model Predictions and Field and Pilot-Scale Experiments
6. Survey of Distribution System Pressure Management Practices
7. Characterize Propagation of Pressure Events through Water Distribution Systems to Improve Pressure Management Approaches

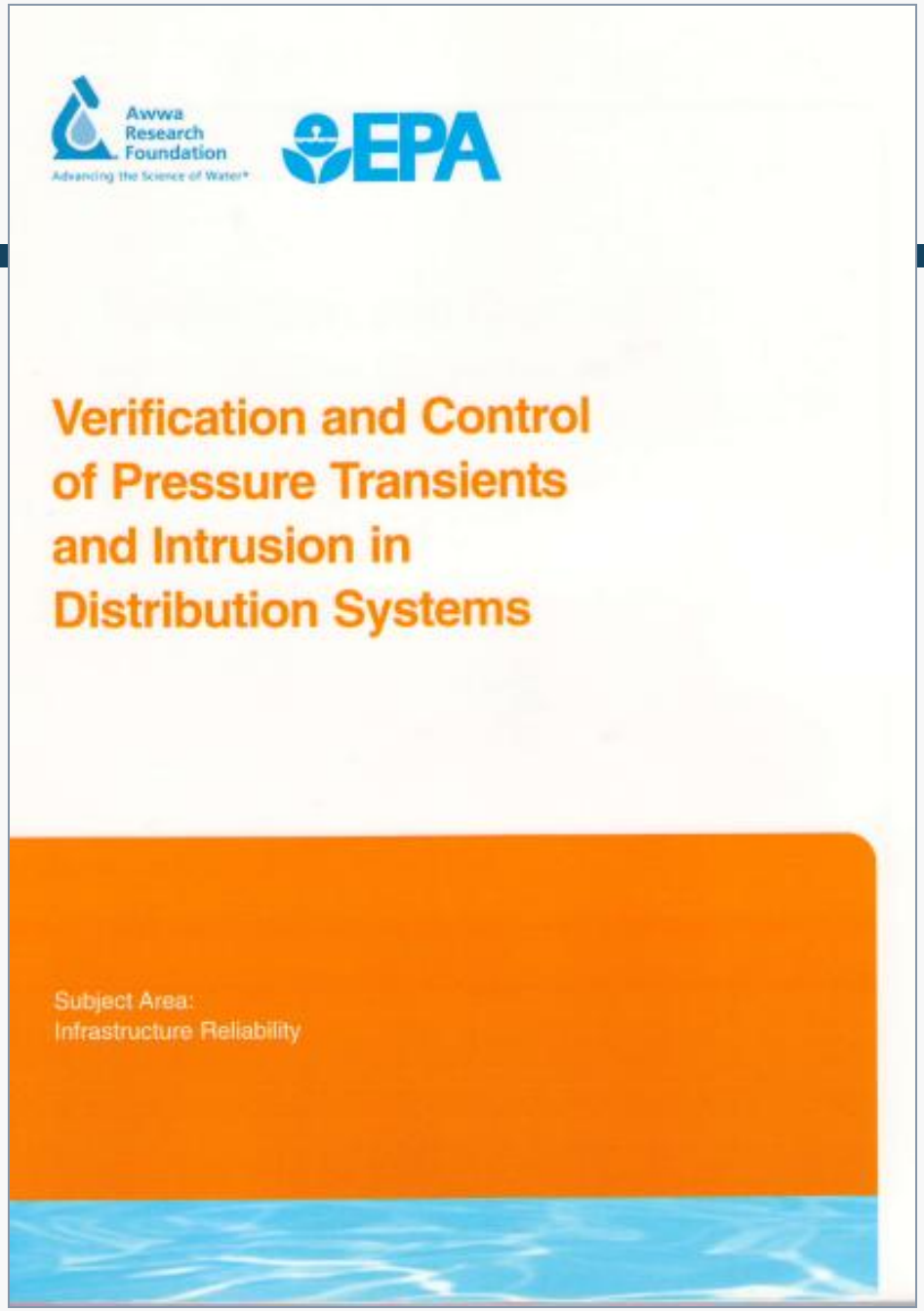
High Priority Project Areas

8. Targeted Surveys to Obtain Information on State and Local Regulations, Policies, Manufacturing Practices and Guidelines for Distribution Systems
9. Best Practices to Minimize Risks Associated with Cross Connections and Backflow
10. Best Practices for Minimizing Risks Associated with Storage Facilities

5 of the 10 High Priority Project Areas are Related to Pressure and Potential Impacts on Public Health

How Does Pressure Impact Public Health?

- Adequate Distribution System Pressure Can Prevent:
  - Backflow and backsiphonage through unprotected cross-connections
  - Intrusion through leaks, submerged air-vac valves
  - Main breaks and leaks


Awwa
Research
Foundation
Advancing the Science of Water
EPA
Verification and Control of Pressure Transients and Intrusion in Distribution Systems
Subject Area:
Infrastructure Reliability

What is Intrusion?

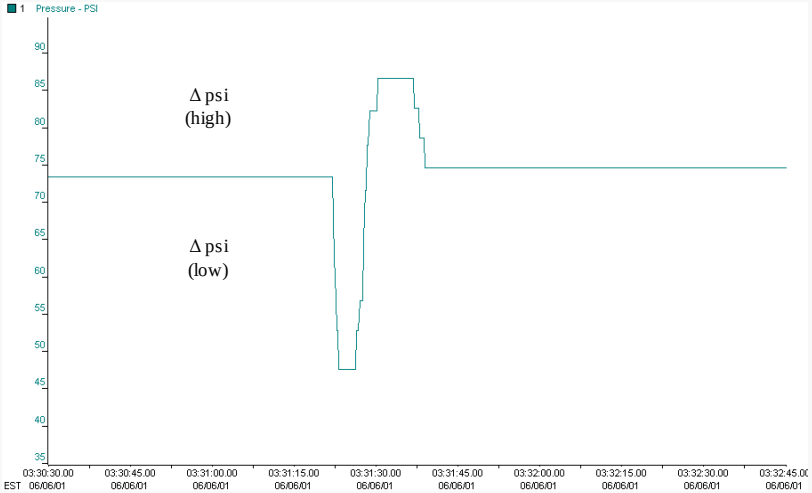
The backflow or backsiphonage of water into a distribution main through leaks, cracks, submerged air valves, faulty seals, or other breaches, due to the development of low or negative transient pressure conditions in the main.

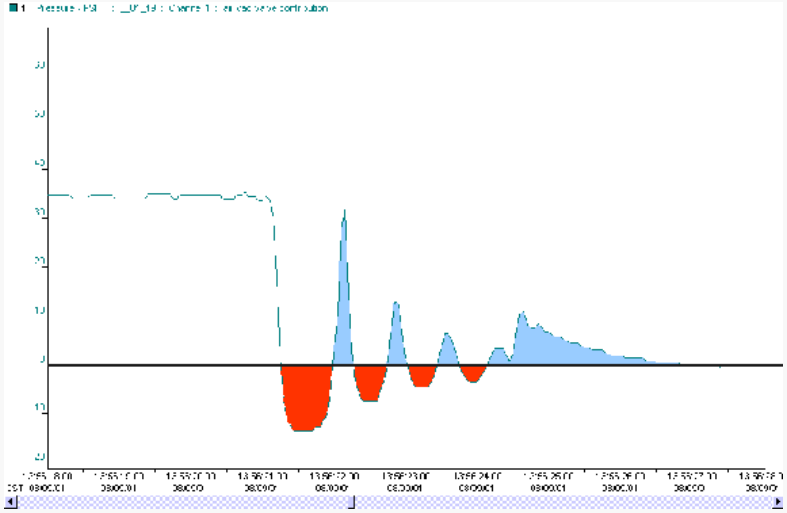
Intrusion *Is Not* the Same As Cross Connection

- Non-potable source is not “piped” to potable source
- Contaminant sources are in the external environment
- Intrusion is more of a transient event
- Driving forces may be the same, however

What is a Pressure Transient?

- Development of instantaneous low or negative pressure wave due to a sudden velocity change
- For sudden valve closure:
  - Compression of water on upstream side
  - Decompression on downstream side
- Without relief, the pressure wave travels back and forth until dissipated by friction or other dampening factors

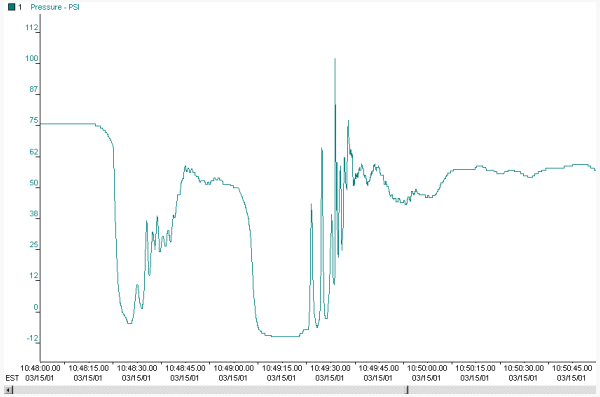




Three Critical Elements for Contamination to Occur Due to Intrusion

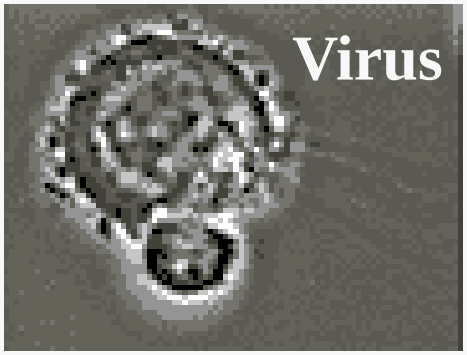
Pathway

Driving Force



Pressure Reduction Event

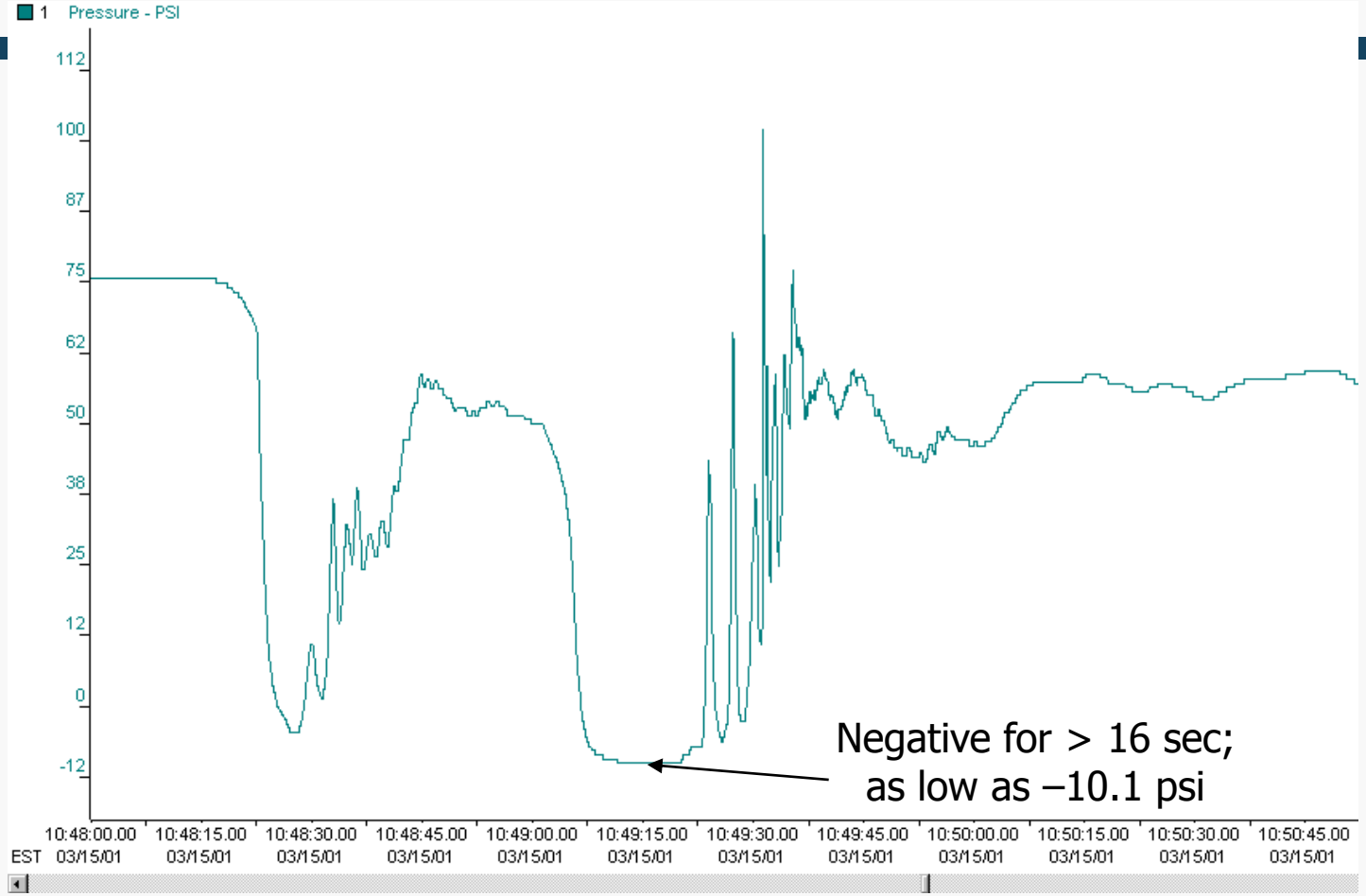
Pathogens



Effect of Pump Drawdown Test

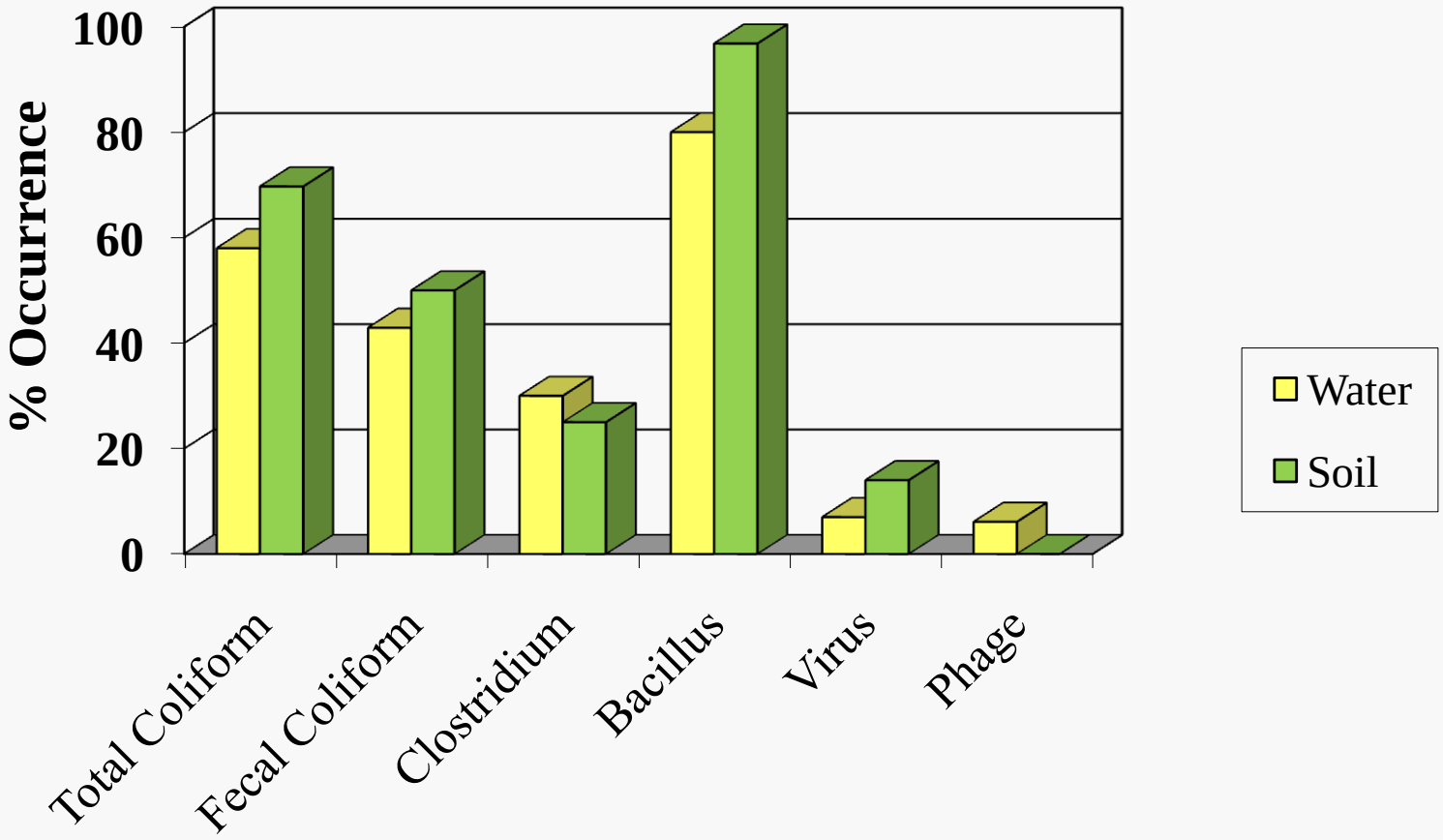
Transients within transmission main, ~5-15 sec duration

Negative Pressures During Pump Test

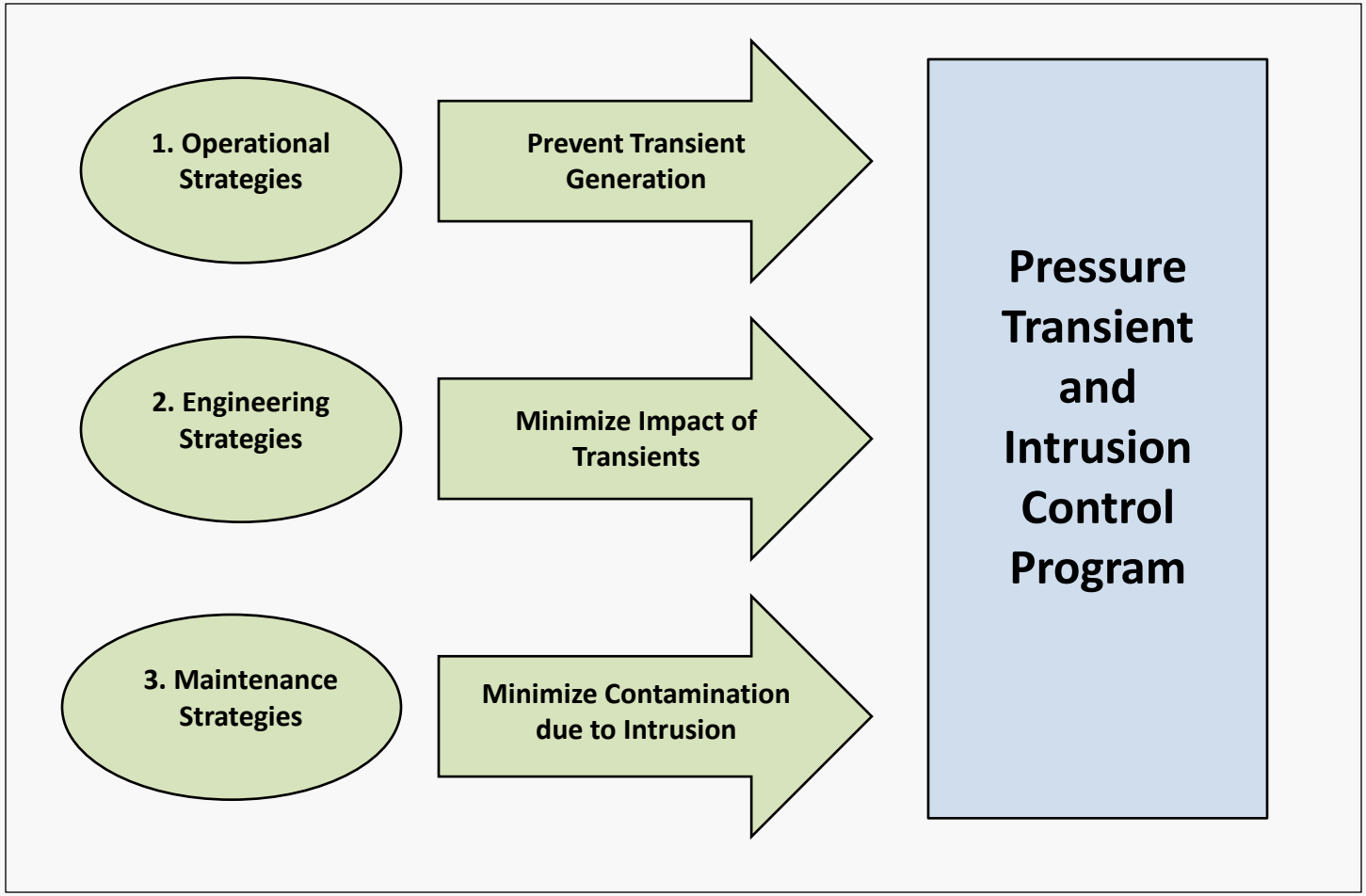


Focus on a negative transient pressure

Microbial Occurrence in Trench Water



Elements of a Comprehensive Intrusion Control Program



Adapted from Friedman et al. 2004. Verification and Control of Pressure Transients and Intrusion in Distribution Systems

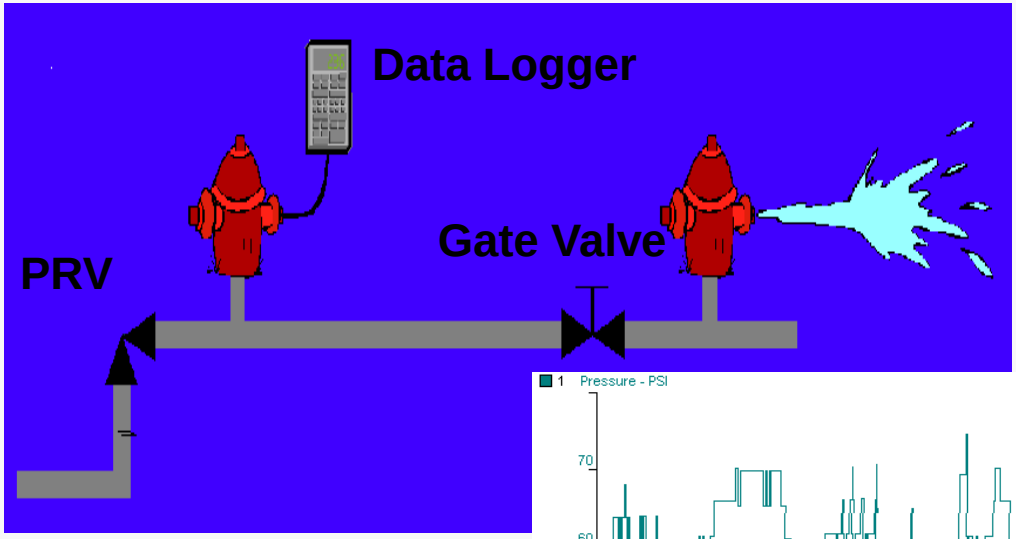
Operational Strategies (Prevent Transients)

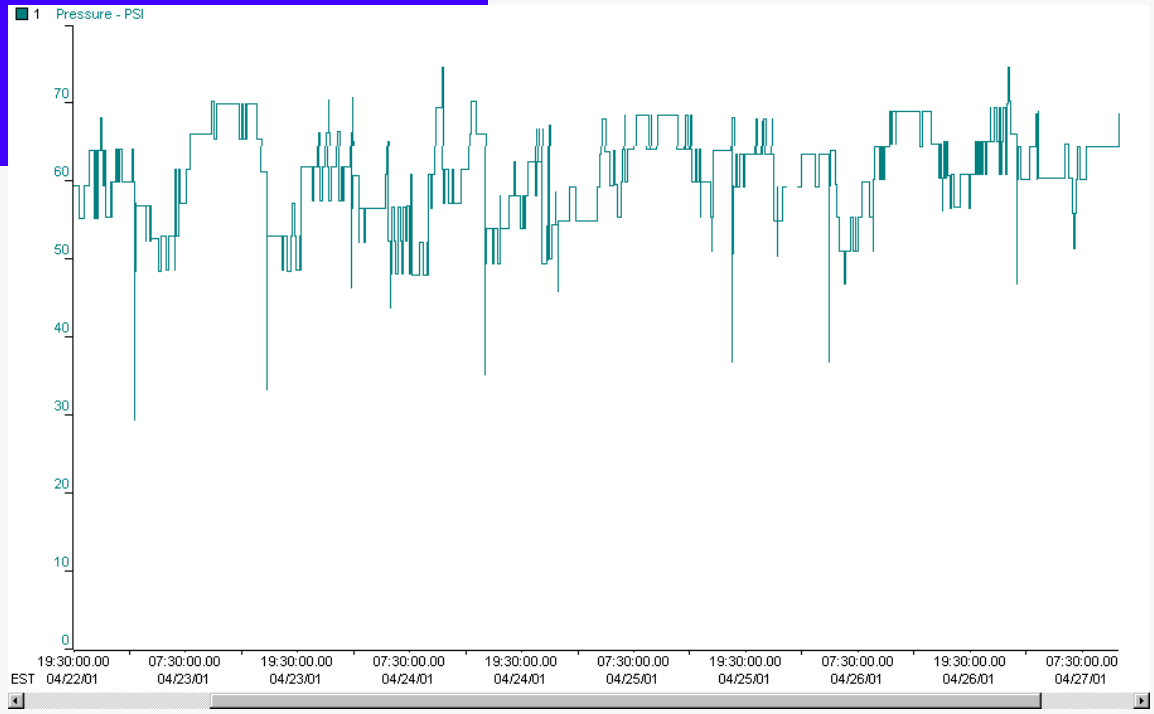
ASDWA. 2003. Unpublished Survey. 34 states responded

30 States require systems to have an operational pressure of at least 20 psi under all flow conditions

- Control velocity changes
  - Hydrant open/close speed
  - Valve operation – closing and opening
  - Pump start-up and shut-down speed
  - Pump start-up and shut-down sequence

Assess Impacts of Flushing Practices on Pressures

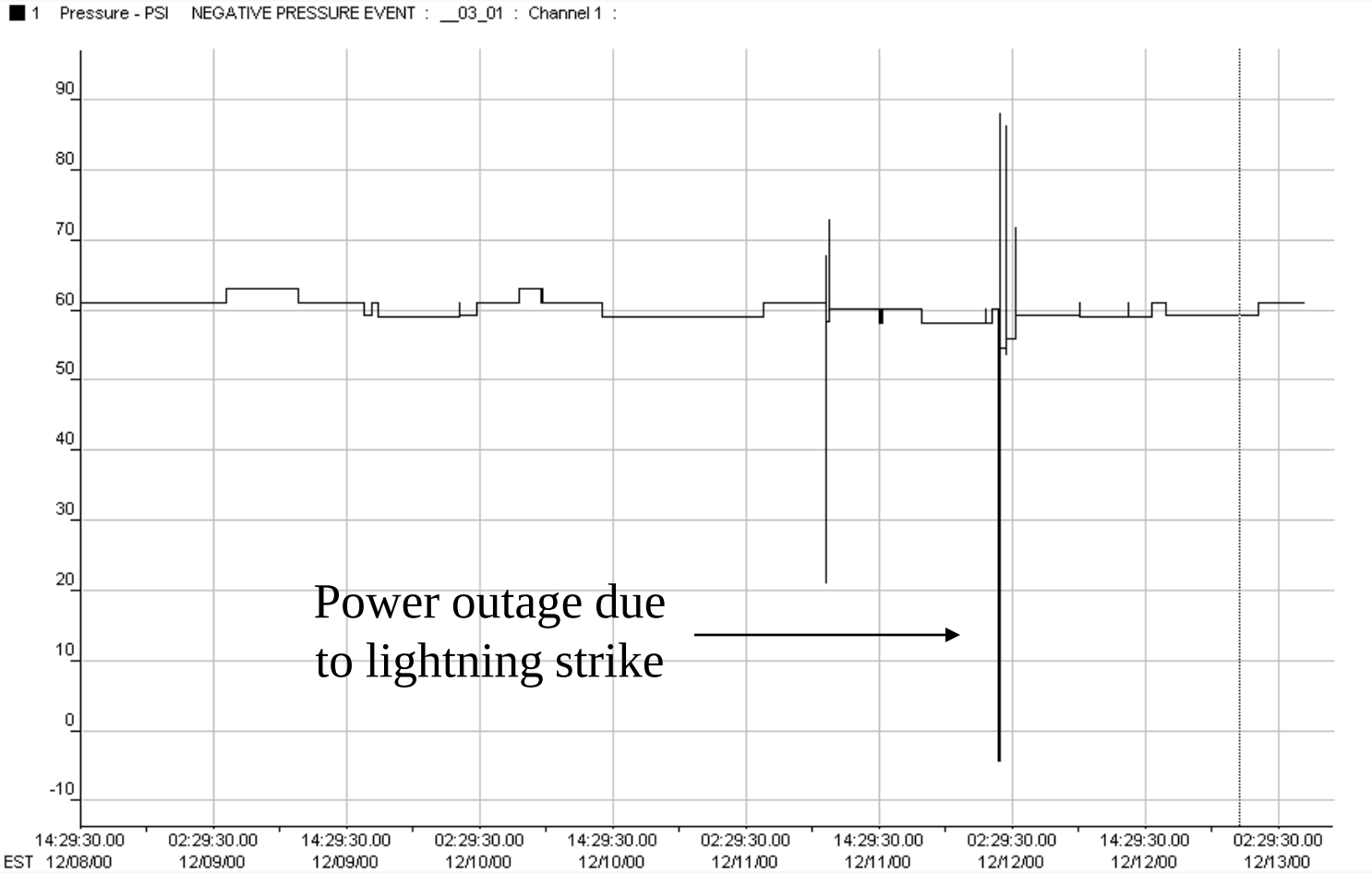




General Recommendations for Sequencing Pump Shut Down

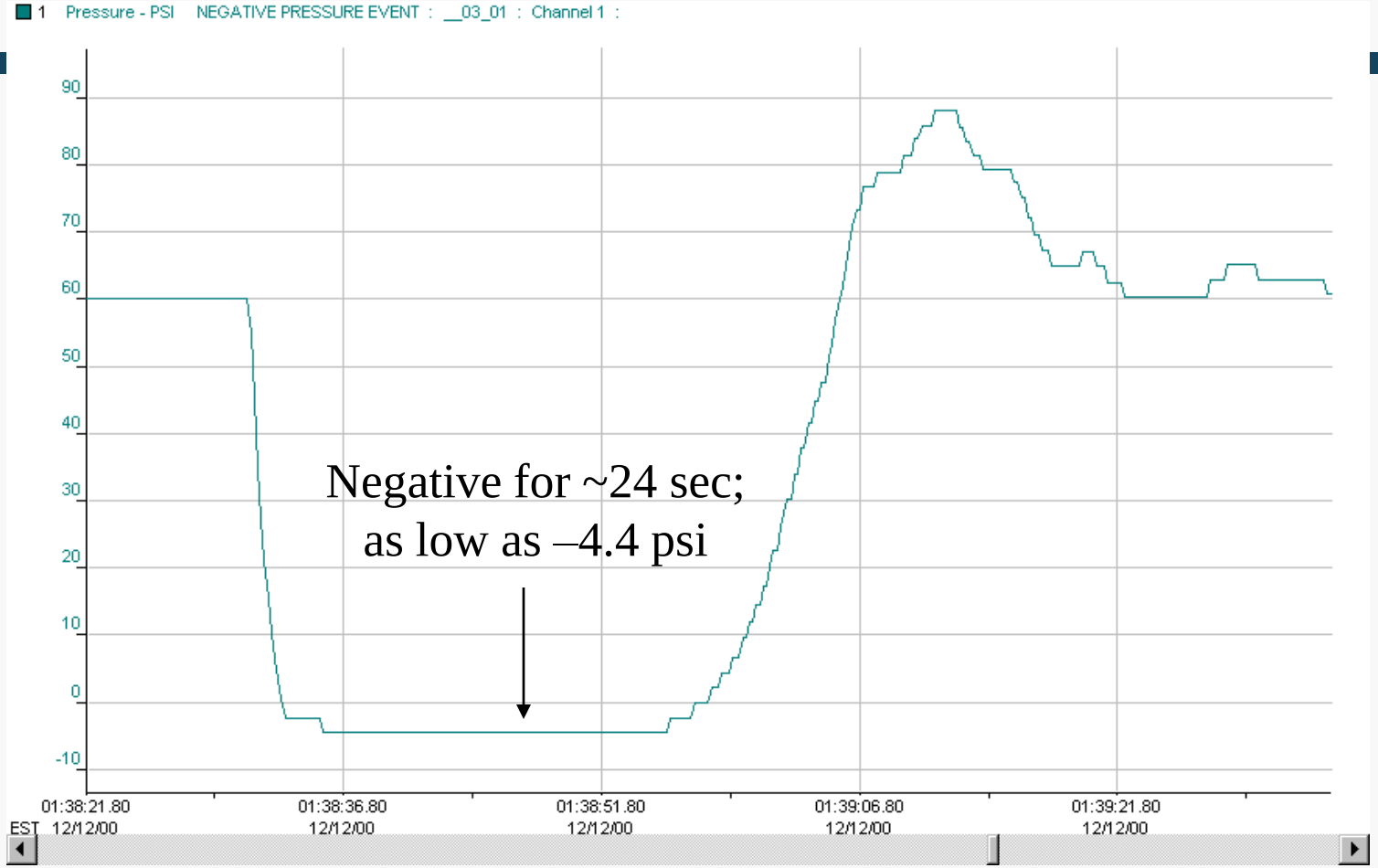
- Stagger pump shut-down sequence so that the magnitude of the change in flow at any one time is reduced
  - Worst-case scenario is a power outage when all pumps shut down at the same time

Pressure During Routine Monitoring



Transient follows a power outage at a pumping station

Pressure During Routine Monitoring



Transient follows a power outage at a pumping station

General Recommendations for Sequencing Pump Shut Down

- By staggering pump shut-down sequence, the magnitude of the change in flow at any one time is reduced
  - Worst-case scenario is a power outage when all pumps shut down at the same time

- **Shut down largest pump first, while other pumps are still providing additional flow**
- **Shut down the smallest pump last and slowest**

Engineering Strategies (Minimize impacts of surges)

- Installation of surge control tanks and other surge control devices
- Floating storage
- Looping dead ends

Generation and propagation of transients can be reduced using these strategies

- Enforce separation distance standards
- Encasement of new mains in areas with high water table

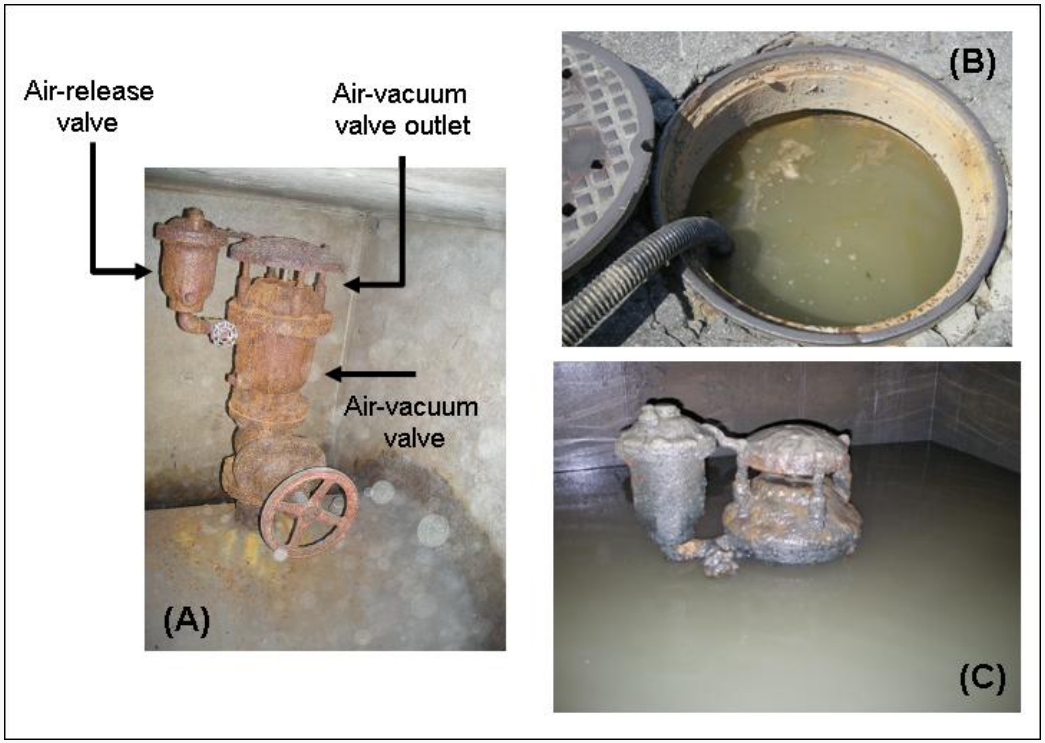
Contaminant entry can be reduced using these strategies

Impact of Air-Vacuum Valves

- Air-vacuum valves can be used to mitigate the development of *negative* pressures
- Air-vacuum valves do not respond to low pressures (e.g. 0 to 20 psi)
  - Designed to open when pressure in the pipe falls below atmospheric
  - At air-vac location, pressure surges cannot be mitigated to pressures greater than 0 psi.
- Air-vacuum valves can dampen a surge at downstream locations

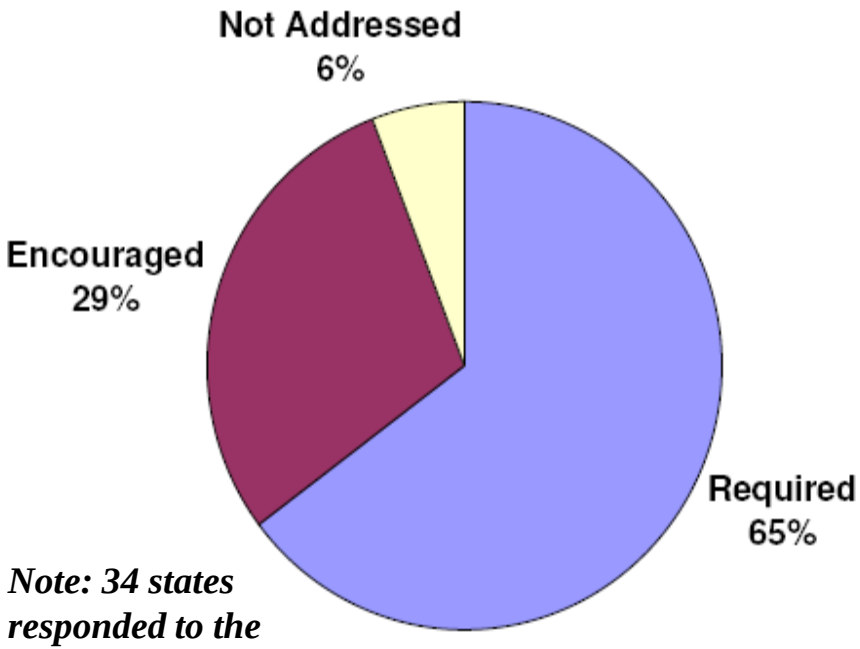
Examples of Below Grade/Submerged Air-Vac Valve

Must be designed so that they are vented and screened above grade!



State Requirements

Does the state require protection of air-release and air vacuum valves?



Note: 34 states responded to the survey

ASDWA. Draft Survey 2003.

Looping Dead-End Mains

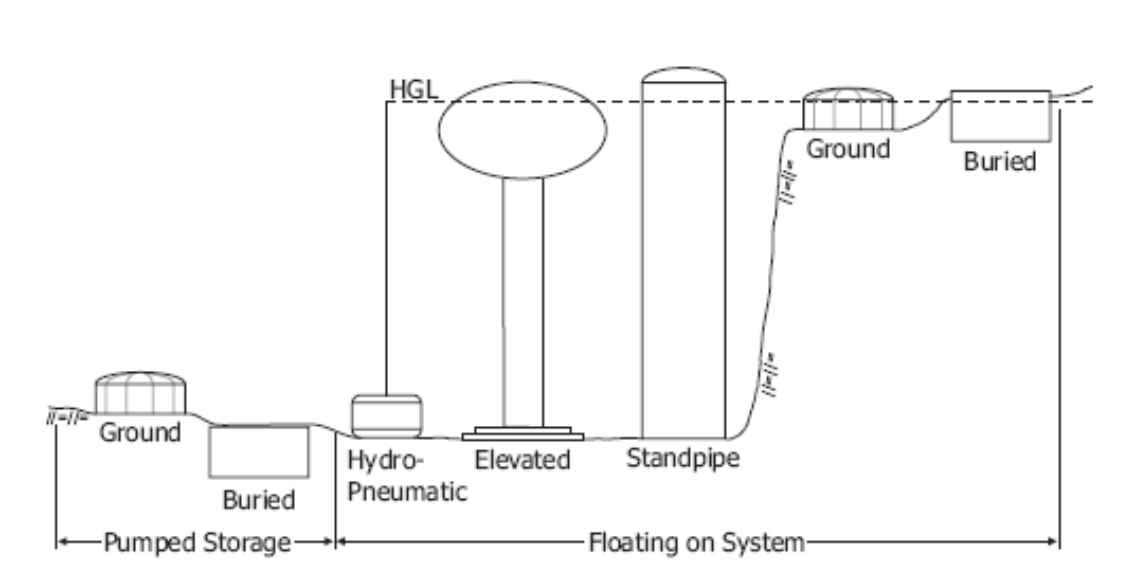
- Interconnections and loops can dampen surges
  - Provide multiple paths for the pressure wave to travel along and dissipate more quickly
  - Allow for multiple water inflow points
- Example: 2400 gpm demand imposed over 30 seconds on 8-inch Line

Condition	Dead-End	Looped
Initial Pressure (psi)	54	60
Min Pressure (psi)	-14 (cavitation)	-8
Flow rate (gpm)	1570	2400

65% increase in demand capacity for looped section

Overhead Storage

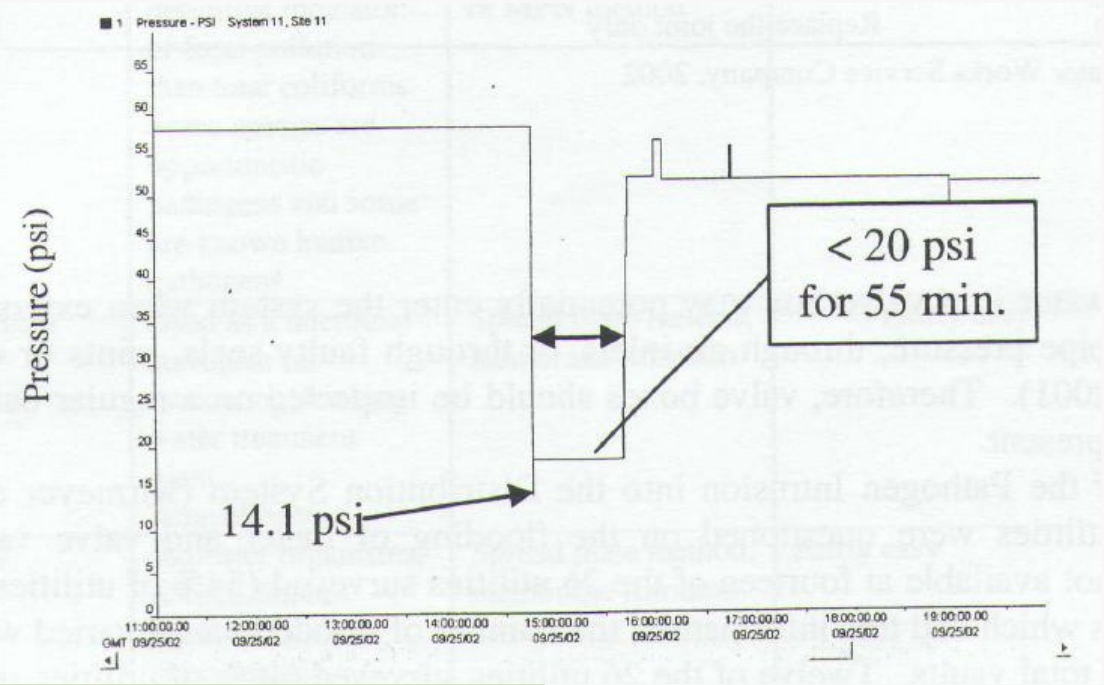
- Finally….overhead storage can *improve* water quality!
  - "Floating" storage can dampen surges
    - Provide backpressure
    - Release water into system during downsurge
    - Receive water during upsurge



Source: Haestad Methods. 2003. Advanced Water Distribution and Modeling

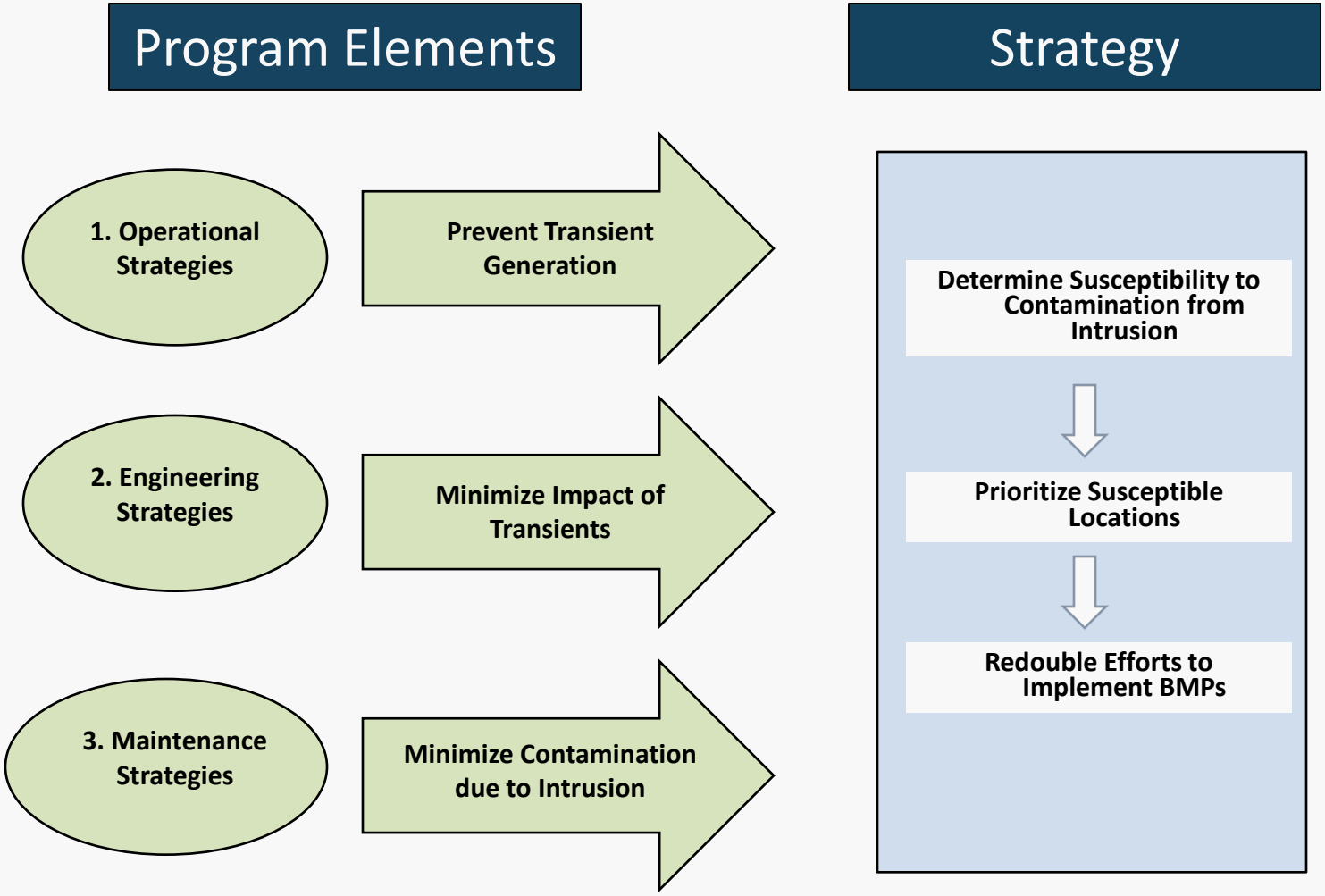
Maintenance Strategies (Minimize contamination potential)

- Leak Detection
- Main Repairs
- Inspections
  - Vaults
  - Trenches



Minimize the "porosity" of the distribution system and reduce pathogen sources

Develop a Comprehensive Intrusion Control Strategy



Developing a Systematic Intrusion Control Strategy (con't)

- Prioritize susceptible areas
  - Pumped (i.e., non-gravity) systems
  - Distribution system mains near by and in simple hydraulic connection to pumps
  - High elevation areas
  - Areas with low static pressures
  - Areas far away from overhead storage
  - Upstream/downstream of active valves in high-flow areas
- Redouble efforts to use BMPs in susceptible areas
  - Increase pressure monitoring
  - Consider need for increased disinfectant residual in specific areas
  - Increase cross connection surveys
  - Increase leak detection
  - Increase inspections

Why Bother????

- Good question….
  - Public health effects have been correlated with low pressure, but not definitively to “intrusion”
  - Porosity of the distribution system will increase as infrastructure ages
  - Intrusion is one of the top ranked issues for further study in the Revised Total Coliform Rule AIP – more to be learned

Whether or not you are an “intrusion believer”….all of the control strategies described here are good industry practices to maintain distribution system water quality!

Questions?

melinda@confluence-engineering.com

confluence ENGINEERING GROUP LLC
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