Effective Microbial Control Strategies for Main Breaks and Depressurization

Project 4307

Sponsored by the Water Research Foundation and the U.K. Drinking Water Inspectorate

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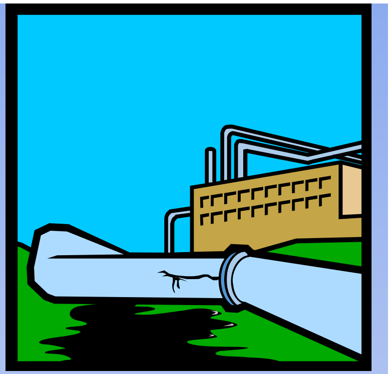
Existing Water Main Repair Practices



Pressure vs depressurization

- Maintain pressure: no intrusion = no risk
- Depressurized: risks from intrusion of contaminants

Lack of risk management structure

- Empirical, highly variable, and unknown level of risk control
- Inadequate or excessive flushing and/or disinfection
- Inconvenient to customers (wait time and/or BWA)
- Variations in documentation of compliance

Project Purpose

Improve utility responses to main breaks and depressurization events to better protect public health.

Project Objectives

1. Evaluate the effectiveness of disinfection and operational practices to mitigate risks.

2. Identify parameters to quantify the level of control achieved.

Project Overview

- 2010 Solicited Research Program

- Project Schedule:
  - Project Start: October 2010
  - Project End: March 2014

- Project Budget:
  - Cash: $350,000
    (= $30,000 (UK DWI) + $320,000 (WaterRF)
  - Third Party Contribution: $331,000
  - Total: $827,560

Participating Utilities

Project Approach

STEP 1	Define Terminology and Establish the Baseline of Practice
STEP 2	Conduct Laboratory and Pilot Studies and Risk Modeling
STEP 3	Identify/Pilot Test Field and Monitoring Activities
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STEP 5	Prepare Work Products and Final Report

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Step 1 Questionnaire

- Intended to gather data and procedures
- Questionnaire distributed with follow-up calls when needed
- Representative sample of industry
- Basis for selecting "Featured Programs"

What is the rate of main breaks (i.e. # / mile) that are encountered by your utility annually?

What criteria do you use for release-to-service after repairing a water main break?

What is the typical crew size for repairing water main breaks for pipes larger/ smaller than 16-inches diameter?

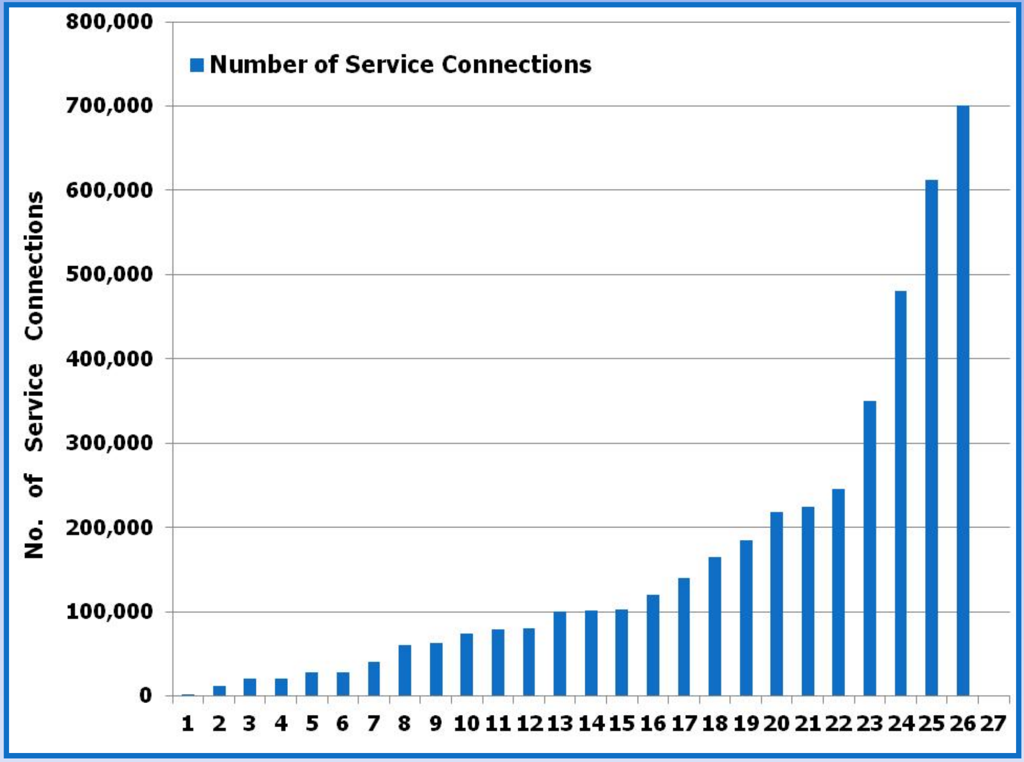
Utility Characteristics

27 Utilities

Population range from 10,000 to over 7 million

System sizes up to 25,000 miles of pipeline

Mix of chlorinated and chloraminated systems



Main Break Data

Results

- Maximum of over 1.4 main breaks/mile/year
- Median of 0.18 breaks/mile/year [Comparable to prior work]
- Most utilities observe a seasonal pattern

Season	Min.	Max.	Average
Winter	18%	79%	38.2%
Spring	4%	25%	14.5%
Summer	5%	39%	22.5%
Fall	7%	38%	24.9%

Program Elements

What Was Found?

- Wide range of practices
- Majority have training; much is informal
- Majority follow parts of AWWA Standard C651 or U.K. Technical Guidance Notes

AWWA Method	Utilities
Trench Treatment	9
Swabbing of Pipe	19
Flushing	24
Disinfection Operation	17
Bacteriological Tests	17

Issues

What Was Found?

- Pressure management
- Boil Water Advisories

Techniques	Utilities
Maintain Minimal Pressure	12
Isolation with No Flow	6
Both	9

Featured Programs

Fort Worth, TX

- Emergency response
- Leak detection procedures
- Excavation pit procedures
- Responses tied to type of break
- Flow chart for Boil Water Advisory (BWA) actions

Los Angeles (LADWP), CA

- Pollution prevention
- Disinfection and dechlorination
- Training materials with quizzes
- Flushing protocols

Featured Programs (Cont.)

New Jersey American Water

- Comprehensive Boil Water Advisory (BWA) guideline

Boulder, CO

- Main break notification and communication protocols

Charlotte-Mecklenburg, NC

- Training materials and performance evaluations

Denver, CO

- Flowchart for risk assessment

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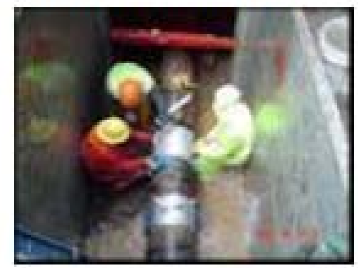
Microbial Risk Modeling (Concept)

1. Pathogen levels in sewage
(Meta-analysis of occurrence levels from literature)

2. Main breaks and depressurization
(Sewage intrusion and dilution)

3. Main break repairs and back to service: a) Flushing; b) Disinfection



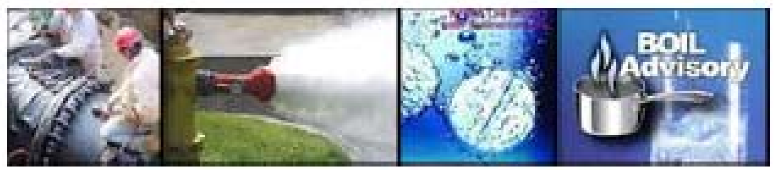
4. Individual water intake

5. Dose-response models
(Collected from literature)

6. Risk characterization
(Monto-Carlo simulations in Mathematica 8.0)

7. Risk management options

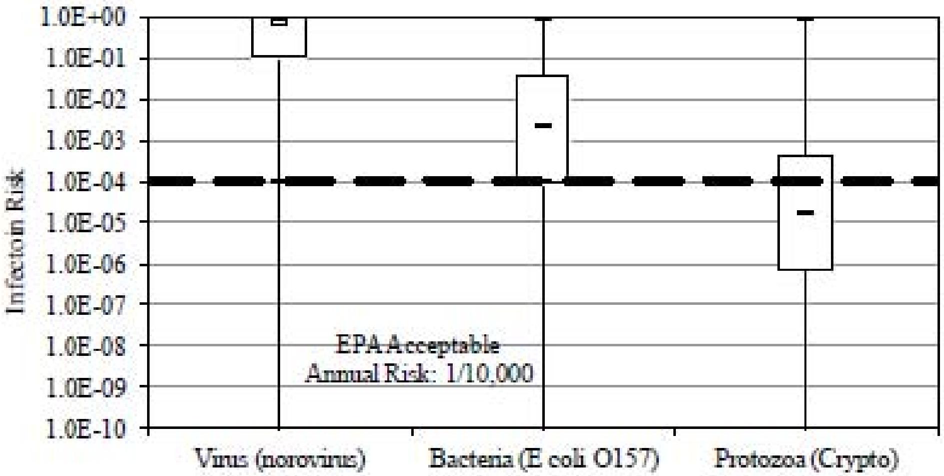
a) Compare with an acceptable annual risk of 10^{-4}
b) Flushing, disinfection, boil water advisory, etc.

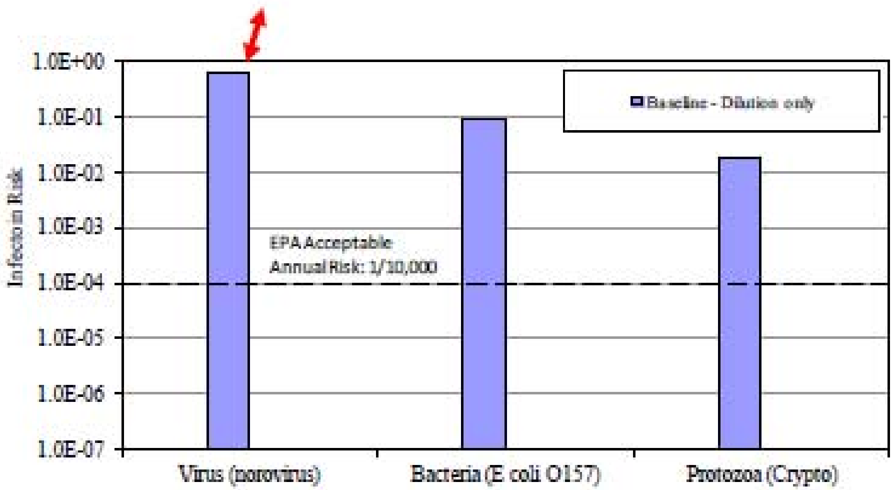


What are the baseline risk levels?

- Main break and depressurized
- Sewage intrusion 0.01-1.0% (i.e., 2-4 log of dilution)

Significant risks, especially from virus (Mean risk of 0.59)

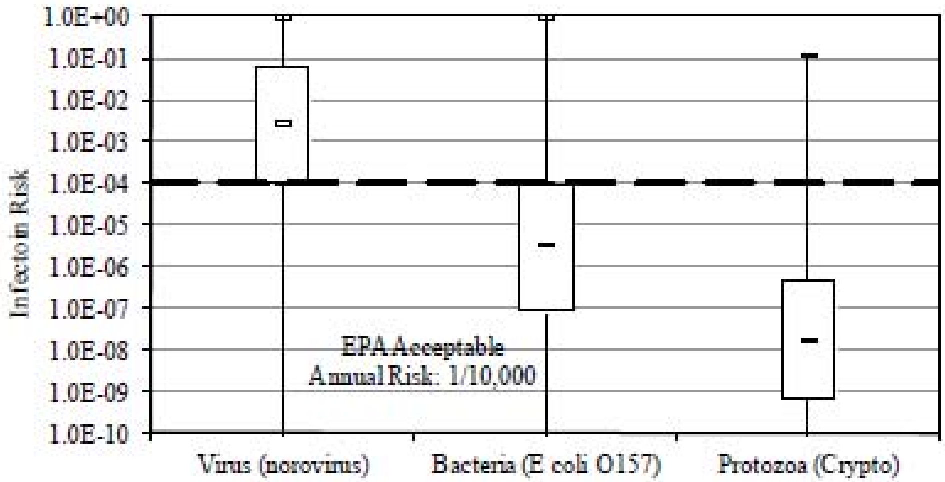


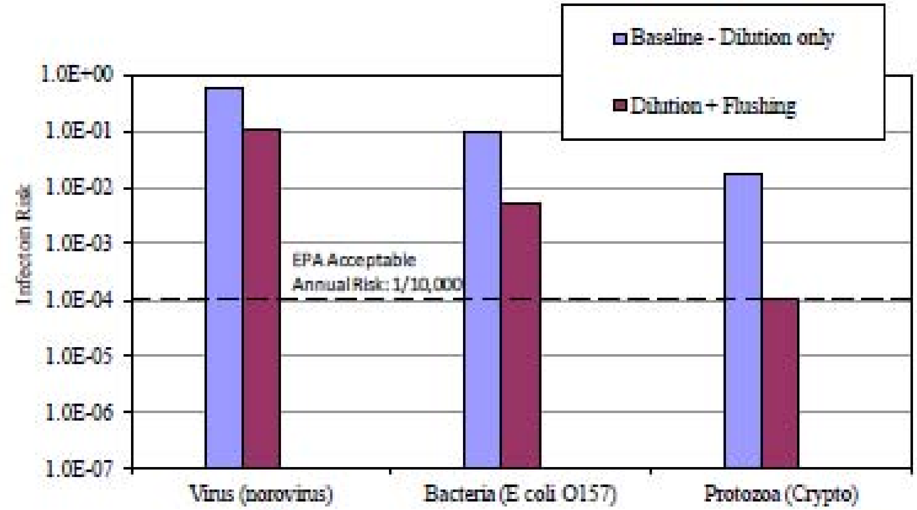


Randomness of infection risks

How effective is flushing to reduce the risks?

- Pathogens attached to soil particles
  - All suspended pathogens removed by flushing
  - Assume flushed at a velocity above the threshold velocity and achieved 2-3 log removal



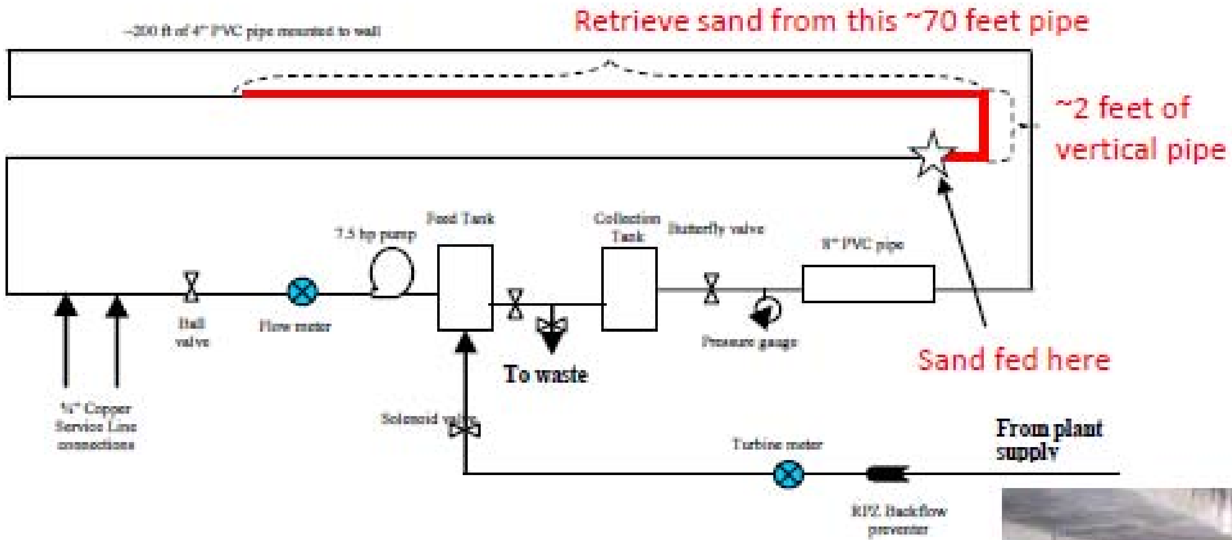


Infection risks reduced by 2-3 logs

Flushing is effective, some risk may still remain high (e.g. mean risk of 0.11 for virus).

Flushing Experiments

- **Evaluate flushing effectiveness on particle removal**
  - Using sand as surrogate for soil particles (conservative)
  - Flushing velocity and duration
  - Particle size, biofilm, and tuberculation



Flushing Result Implications

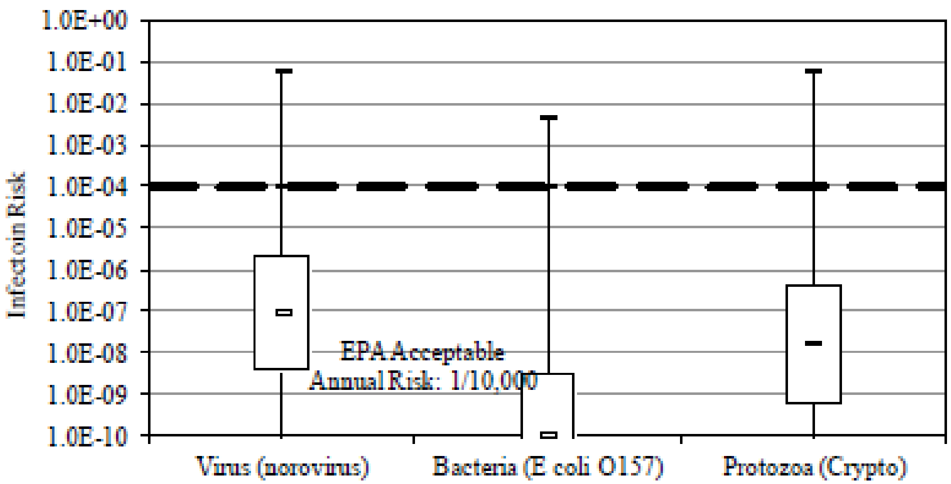
- Flushing >3.5 ft/sec may remove soil-attached pathogens by 2.5-3.0 log (using sand as surrogate for soil particles).

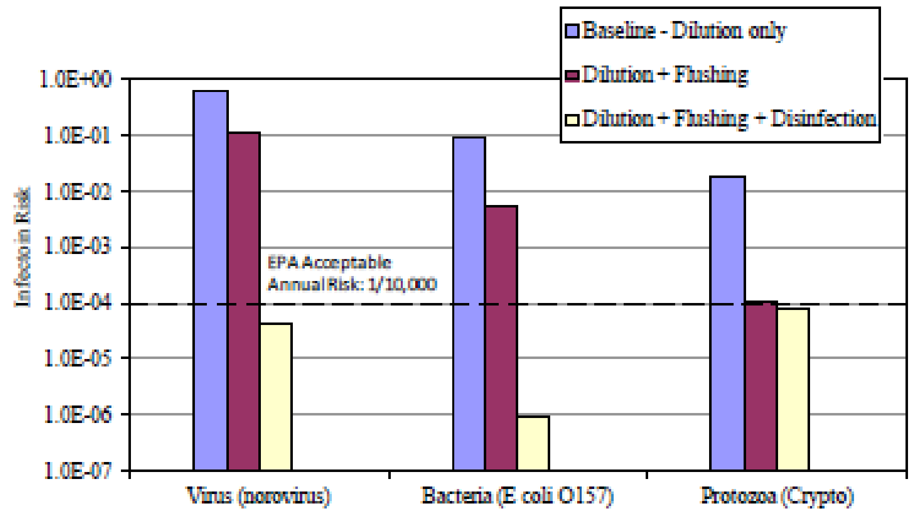
- For heavily tuberculated or larger diameter (>16-in) pipes, flushing may not be as effective. More disinfection may be necessary. The *Crypto* infection risk may become the controlling risk.

Flushing Metrics				
Diameter (inch)	Volume per 100 Feet Pipe (gal)	Minimum Required Flow Rate (gpm) 3 feet/sec	Minimum Required Flow Rate (gpm) 4 feet/sec	Minimum Required Flow Rate (gpm) 5 feet/sec
4	60	120	160	200
6	140	270	360	450
8	260	480	630	790
10	400	740	980	1,300
12	580	1,100	1,500	1,800
14	790	1,500	2,000	2,400
16	1,040	1,900	2,600	3,200
18	1,320	2,400	3,200	4,000
20	1,630	3,000	4,000	4,900

How effective is disinfection to reduce the risks?

- What levels of disinfection will be needed for risk reduction?
  - Disinfection had no reduction on the *Crypto* levels
  - Need 4-5 logs of inactivation of virus and bacteria





Virus and bacteria infection risks reduced by 4-5 logs, *Crypto* infection risk remained the same

Mean risks of all three pathogens are below the 1/10,000 level.

Overall Main Break Risk Assessment (Conservative)

Intrusion of raw sewage

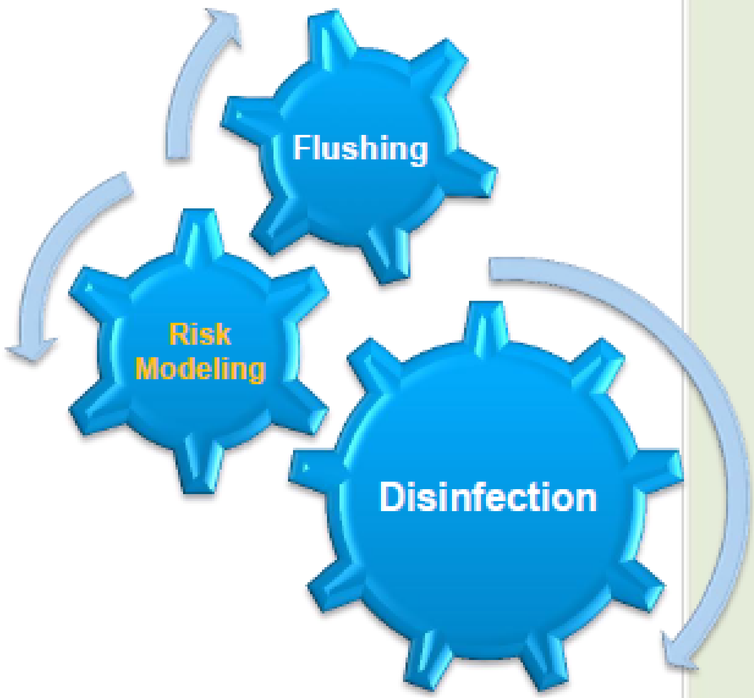
- Leaking sewage nearby, worst scenario (compared with pit waters)

Using sand as surrogate for flushing

- Sand is more difficult to flush, but provides minimal shielding from disinfection
- Lighter soil particles (e.g. peat) provide most protection, but easier to flush out.

Using the *CT* of peat-attached virus for disinfection

- Sand or clay: 4-log inactivation *CT* values for free chlorine up to 92 mg/L Cl_2*min
- Peat: 4-log inactivation *CT* values for chlorine up to 1,500 mg/L Cl_2*min



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Step 4: Risk Management Workshop

- April 18-19, 2012
- Mt. Laurel, NJ at American Water
- 30 participants from operating utilities, regulatory agencies, and the project team

Workshop Goals

1. Confirm the applicability of the risk model
2. Confirm the risk model input parameters (e.g., disinfectant concentration, flushing velocity)
3. Identify field activities for the next phase of the study
4. Discuss the applicability of this study as the technical basis for future revision of AWWA Standard C651

Key Results

- Developed four categories of main breaks
- Developed proposed response actions (procedures) for each type of break
- Identified field study objectives

Triage – Determining Risk

Wounded were placed into three categories:

- Those who are likely to live, regardless of what care they receive;
- Those who are likely to die, regardless of what care they receive;
- Those for whom immediate care might make a positive difference in outcome.

Main Break Categories

Type I Break	Type II Break	Type III Break	Type IV Break
• Positive pressure maintained during break	• Positive pressure maintained during break	• Loss of pressure at break site/ local system depressurization	• Loss of pressure at break site/ widespread depressurization
• Pressure maintained during repair	• Pressure maintained until break exposed	• Partially or un-controlled shutdown	• Catastrophic event
• No signs of contamination intrusion	• No signs of contamination intrusion	• Possible contamination intrusion	• Possible / actual contamination intrusion

Type I Main Break Procedures

Procedures
• Excavate to below break
• Maintain pit water level below break
• Repair under pressure
• Disinfect repair parts
• Check residual disinfectant level in distribution system
• No Boil Water Advisory (BWA) or “Do Not Drink” Order
• No bacteriological samples

Type II Main Break Procedures

Procedures
• Excavate to below break
• Maintain pit water level below break
• Controlled shutdown
• Disinfect repair parts
• Conduct low velocity flush
• Check residual disinfectant level in distribution system
• No Boil Water Advisory (BWA) or “Do Not Drink” Order
• No bacteriological samples

Type III Main Break Procedures

Procedures
• Uncontrolled shutdown
• Document possible contamination
• Disinfect repair parts
• Conduct scour flush (3 ft/sec min.)
• Conduct slug chlorination (CT = 100 mg-min/L)
• Check residual disinfectant level in distribution system
• Instruct customers to flush premise plumbing
• No Boil Water Advisory (BWA) or “Do Not Drink” Order*
• No bacteriological samples*

**Based on risk model results, application of the proposed procedures, and acceptance by regulatory agencies*

Type IV Main Break Procedures

Procedures
• Catastrophic failure response
• Document possible contamination
• Shut-off customer services in affected area
• Disinfect repair parts
• Conduct scour flush (3 ft/sec min.)
• Conduct slug chlorination (CT = 100 mg-min/L)
• Instruct customers to flush premise plumbing
• Check residual disinfectant level in distribution system
• Issue BWA or “Do Not Drink” Order
• Bacteriological sampling required

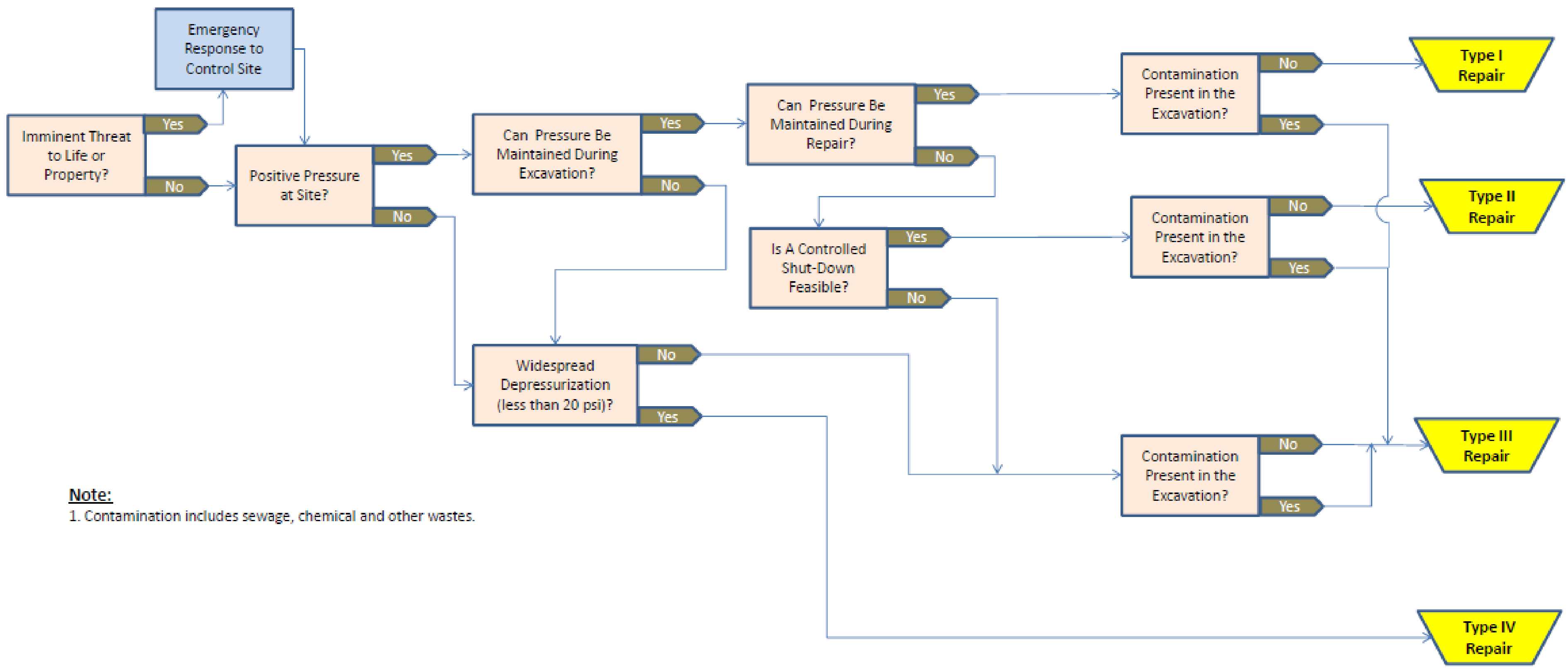
Frequency of Break Type

Estimated % of Total Breaks			
Type I	Type II	Type III	Type IV
50%	35%	10%	<5%

Key Triage Questions

- Are there factors requiring an immediate shutdown?
- Is there positive pressure?
- Can positive pressure be maintained during excavation?
- Can positive pressure be maintained during repair?
- Is there site contamination?
- Is there widespread depressurization?
- Are there critical customers that need special attention?

Main Break Risk Triage Flowchart



Note:

1. Contamination includes sewage, chemical and other wastes.

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Field Beta Testing

- **Main Break Triage Table (The 4 Types)**
- **Main Break Risk Triage Flowchart**
- **Main Break Repair Guideline & Checklist**
- **Field Beta Testing Procedures**
  - Pressure Maintenance and Verification
  - Field Monitoring for Chlorine Residuals
  - Scour Flushing
  - Slug Disinfection

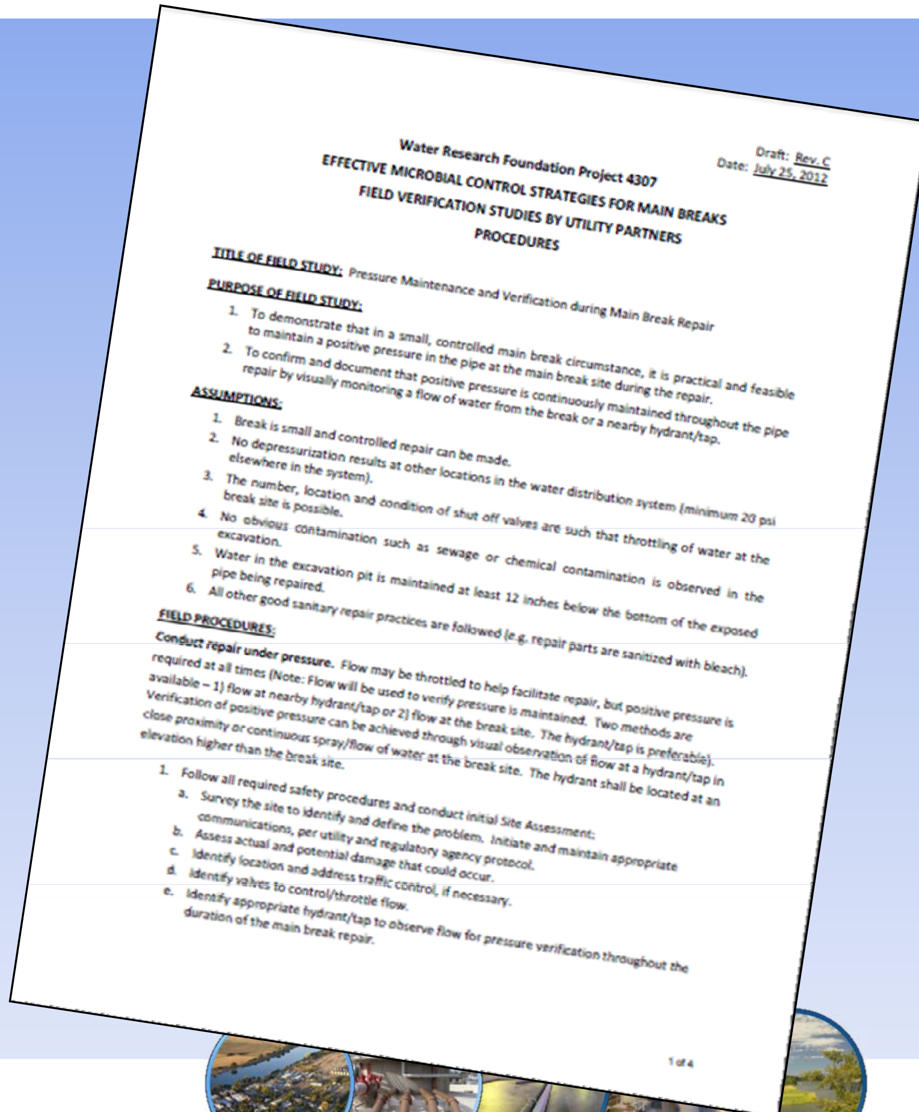
Main Break Repair Guideline & Checklist

Checklist to be used for:

- Main break repair and documentation
- Step-by-step description of repair procedures that needs to be followed in the field
- Will help to decide on type of breaks and the responses required for repair

Testing Procedures

- Written protocols
- Checklist forms
- Group training and Q&A
- Tested on actual breaks by utility crews
- Documented with feedback provided



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Date: July 25, 2012

Water Research Foundation Project 4307
EFFECTIVE MICROBIAL CONTROL STRATEGIES FOR MAIN BREAKS
FIELD VERIFICATION STUDIES BY UTILITY PARTNERS
PROCEDURES

TITLE OF FIELD STUDY: Pressure Maintenance and Verification during Main Break Repair

PURPOSE OF FIELD STUDY:

1. To demonstrate that in a small, controlled main break circumstance, it is practical and feasible to maintain a positive pressure in the pipe at the main break site during the repair.
2. To confirm and document that positive pressure is continuously maintained throughout the pipe repair by visually monitoring a flow of water from the break or a nearby hydrant/tap.

ASSUMPTIONS:

1. Break is small and controlled repair can be made.
2. No depressurization results at other locations in the water distribution system (minimum 20 psi elsewhere in the system).
3. The number, location and condition of shut off valves are such that throttling of water at the break site is possible.
4. No obvious contamination such as sewage or chemical contamination is observed in the excavation.
5. Water in the excavation pit is maintained at least 12 inches below the bottom of the exposed pipe being repaired.
6. All other good sanitary repair practices are followed (e.g. repair parts are sanitized with bleach).

FIELD PROCEDURES:

Conduct repair under pressure. Flow may be throttled to help facilitate repair, but positive pressure is required at all times (Note: Flow will be used to verify pressure is maintained. Two methods are available – 1) flow at nearby hydrant/tap or 2) flow at the break site. The hydrant/tap is preferable). Verification of positive pressure can be achieved through visual observation of flow at a hydrant/tap in close proximity or continuous spray/flow of water at the break site. The hydrant shall be located at an elevation higher than the break site.

1. Follow all required safety procedures and conduct initial Site Assessment:
   a. Survey the site to identify and define the problem. Initiate and maintain appropriate communications, per utility and regulatory agency protocol.
   b. Assess actual and potential damage that could occur.
   c. Identify location and address traffic control, if necessary.
   d. Identify valves to control/throttle flow.
   e. Identify appropriate hydrant/tap to observe flow for pressure verification throughout the duration of the main break repair.

1 of 4

Pressure Verification

To confirm and document that positive pressure is continuously maintained throughout the pipe repair by visually monitoring a flow of water from the break or a nearby hydrant/tap

- Check system pressure through SCADA
- Identify location for monitoring
- Throttle flow to make repair
- Maintain pit water below pipe
- Disinfect repair parts
- Backfill trench
- Check residual

Measuring Disinfectant

To confirm ambient water with a disinfectant residual has been brought back into the system prior to returning to normal service

- Train repair crews
- Maintain instrument calibration
- Collect sample(s) from repaired main
- Follow step-by-step analysis procedures
- Compare to normal operating conditions

Scour Flushing

To confirm and document that a minimum of 3.0 ft/sec velocity (in the largest diameter pipe) was achieved during flushing

- Flush from both directions, where feasible
- Slowly fill pipeline to evacuate air
- Achieve scour velocity for largest affected pipe*
- Run for min. three pipe volumes
- Check residual

**Several alternate methods to verify flow rate are provided in the guidance*

Pipe Diameter	Flushing Velocity	Flow in Pipe		
(Inch)	(ft/sec)	(ft^3/sec)	(gpm)	Three Pipe Volume/Linear ft of Pipe Length (gal)
2	3.0	0.07	29	0.49
4	3.0	0.26	118	1.96
6	3.0	0.59	264	4.41
8	3.0	1.05	470	7.83
10	3.0	1.64	735	12.24
12	3.0	2.36	1058	17.62
16	3.0	4.19	1881	31.33

Slug Chlorination

To demonstrate that slug chlorination (CT of 100 mg-min/L), following a main break repair that involves loss of pressure at the break site was implemented to achieve adequate disinfection

- Conduct scour flush first
- Chlorinate the main at targeted residual – maintained for full contact time
- Evacuate highly chlorinated water (with dechlor)
- Flush premise plumbing where applicable
- Check residual

Results

- Many Type I and II breaks
- Very few Type III breaks
- Pressure Verification – Successful
- Field Monitoring of Chlorine – Successful
- Flushing – Mostly Successful
- Slug Chlorination – Limited Success

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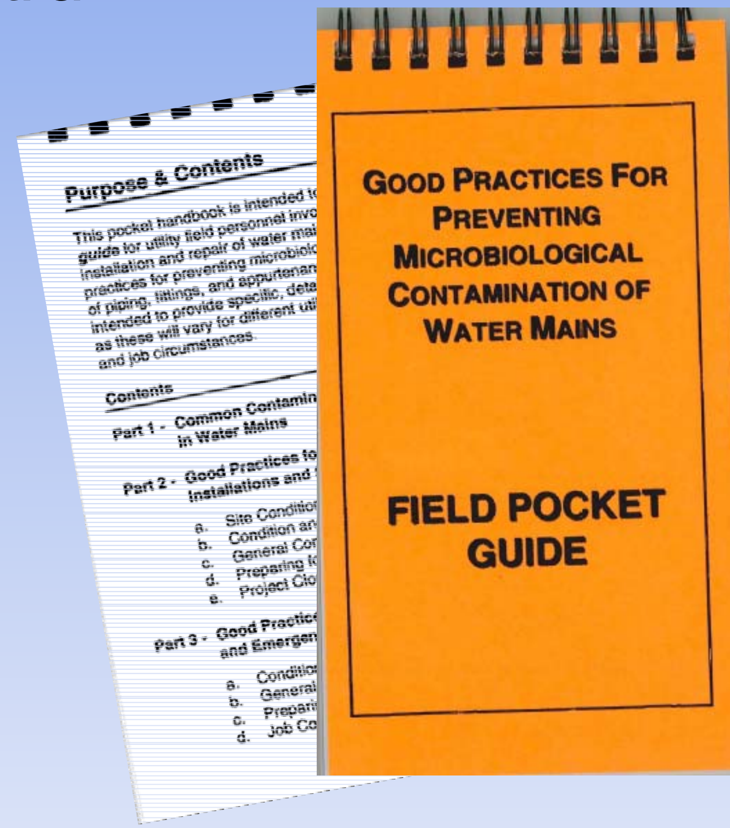
Major Work Products

- New / Revised AWWA Standard
- SOP's for Best Practices
- Surveys & Case Studies
- Draft & Final Report
- Risk-Based Management Strategy



Updates to AWWA C-651

- C-651 deals with new water mains
- Limited applicability for emergency repairs
- Still being used for repairs though
- Update in progress

C-651 – Key Revision Concepts

- Maintain **pressure** until a shutoff is secured
- Keep all pipe and repair **materials clean** and sanitary
- **Prevent runoff** and contamination from entering pipe and trench
- Control the **water in the trench**
- Take added precautions if trench is affected by a local sewer
- Liberally use chlorine by **spray and swab** applications
- Properly **flush**
- Advise affected customers to flush their **service lines**
- Ensure that a **chlorine residual** is restored in the local distribution system when the main is back in service

Effective Microbial Control Strategies for Main Breaks and Depressurization

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