EXECUTIVE SUMMARY

OBJECTIVES

The purpose of this project was to improve utility responses to main breaks and depressurization events to better protect public health. The specific project objectives included the following:

- Evaluate the effectiveness of disinfection and operational practices to mitigate microbial risks
- Identify parameters to quantify the level of control needed to mitigate the risks of microbial contamination from main breaks and depressurization events

BACKGROUND

By some estimates, there are over 700 water main breaks in the United States every day that require repair. This is in addition to the breaks and repairs that occur daily in other countries in North America, the United Kingdom, and other locations around the world. Some of these breaks are small, do not involve depressurization, and are fixed with a repair clamp, often maintaining some pressure in the pipe. For this type of main break, there is likely little chance of microbial contaminants entering the distribution piping network. At the other end of the spectrum, some breaks are much larger, with catastrophic events occurring on large transmission lines. These larger events may result in widespread depressurization for an extended period of time and may require removing and replacing sections of pipe and valves. This type of break could result in the entry of microbial and chemical contaminants both at the repair site and in the depressurized areas of the distribution system away from the break area.

APPROACH

The study, which was co-funded by the Water Research Foundation and the Drinking Water Inspectorate, included the following sequence of activities:

Step 1: Define Terminology and Establish the Baseline of Practice

This step developed a common understanding of the issues (both in the United States and the United Kingdom), provided a framework for evaluating risks, and identified the current practices in use today.

Step 2: Conduct Laboratory and Pilot Studies and Risk Modeling

This step formed the scientific basis for evaluating risks and their respective response measures. To model the risk of contamination during a main break, four factors were considered:

- The disinfectant demand of the contaminant
- The inactivation kinetics of microbial contaminants
- The effectiveness of contaminant removal by flushing

- The risk of the material remaining after disinfection and/or flushing

Step 3: Identify/Pilot Test Field and Monitoring Activities

Step 3 translated the science from the laboratory into the real world, ultimately including the beta testing of actual risk mitigation procedures. This step was based on existing and potential field practices that could be used by utilities to mitigate the risks of microbial contamination during a main break repair. There are three main aspects of Step 3:

- Identify field risk reduction strategies
- Develop a monitoring program to confirm disinfectant efficacy
- Beta-test sanitation control strategies

Step 4: Develop Tiered Risk Management Strategy Including Multiple Barriers

Step 4 synthesized the results of the study and developed a tiered risk management strategy. This step included a workshop with utility and regulatory representatives to balance risk management with practical methodologies to form the basis for appropriate response to main breaks.

Step 5: Prepare Work Products and Final Report

The study concluded with a final report and related outreach materials developed to inform drinking water practitioners about the identified best management practices to reduce the risks of microbial contamination from main breaks and depressurization. In addition, a Pocket Guide with sanitation procedures was developed as an add-on to this project.

RESULTS/CONCLUSIONS

As part of the Risk Management strategy, four categories of breaks and responses were developed and summarized:

- Type 1 — Positive pressure maintained during excavation and repair
- Type 2 — Positive pressure maintained during excavation, followed by controlled shut down for repair
- Type 3 — Loss of pressure at break site/possible local depressurization
- Type 4 — Catastrophic failure, loss of pressure at break site, and widespread depressurization

Table ES.1 was developed to help guide the process of categorizing and responding to main breaks.

Table ES.1
Main Break Types and Responses

Type 1 Break	Type 2 Break	Type 3 Break	Type 4 Break
Positive pressure maintained during break	Positive pressure maintained during break	Loss of pressure at break site/ possible local depressurization adjacent to the break	Loss of pressure at break site/ widespread depressurization in the system
Pressure maintained during repair	Pressure maintained until controlled shutdown	Partial or un-controlled shutdown	Catastrophic event/failure
No signs of contamination intrusion	No signs of contamination intrusion	Possible contamination intrusion	Possible/ actual contamination intrusion
Procedures	Procedures	Procedures	Procedures
Excavate to below break	Excavate to below break	Uncontrolled shutdown	Catastrophic failure response
Maintain pit water level below break	Maintain pit water level below break	Document possible contamination	Document possible contamination
Repair under pressure	Controlled shutdown	Disinfect repair parts	Shut-off customer services in affected area
Disinfect repair parts	Disinfect repair parts	Conduct scour flush (3 ft/sec for 3 pipe volumes)	Disinfect repair parts
Check residual disinfectant level in distribution system	Conduct low velocity flush (flush 3 pipe volume)	Conduct slug chlorination (CT of 100 mg/L-min[3])	Conduct scour flush (3 ft/sec for 3 pipe volumes)
No Boil Water Advisory (BWA)	Check residual disinfectant level in distribution system	Check residual disinfectant level in distribution system and ensure it is adequate	Conduct slug chlorination (CT of 100 mg/L-min[3])
No bacteriological samples	No Boil Water Advisory (BWA)	Instruct customers to flush premise plumbing upon return to service	Instruct customers to flush premise plumbing upon return to service
	No bacteriological samples	BWA – TBD; based on depressurization extent and presence of contamination[1,2]	Check residual disinfectant level in distribution system and ensure it is adequate
		Bacteriological samples - TBD; based on depressurization extent and presence of contamination[1,2]	Issue BWA/ Boil Water Notice or "Do Not Drink" Order
			Bacteriological sampling required

Notes:

1. TBD – To be Determined
2. If depressurization is limited to the pipe section, or area flushed or disinfected, then a boil water advisory and/or bacteriological testing are not needed. However, if the area of depressurization is larger than the treated area, then a precautionary boil water advisory and/or bacteriological testing should be considered.
3. In highly tuberculated pipes, a higher CT should be considered to compensate for possible lower flushing efficiency.

There is an increasing risk of intrusion and contamination associated with the types of breaks proceeding from Type 1 (Minimal Risk) to Type 4 (Highest Risk). Likewise, the suggested mitigation responses are tailored to increase in intensity and effectiveness with each type of break

from 1 to 4. The report also contains a Main Break Risk Triage Flowchart which can be used by utilities to respond to main breaks in effective and efficient ways.

APPLICATIONS AND RECOMMENDATIONS

The following groups can immediately benefit from the results of this project:

- AWWA: updating the AWWA Standards to improve clarity
- Water Utilities: revising existing water utility guidelines and practices to improve sanitation during main break repair
- Regulatory Agencies: revising regulatory requirements to better match the Risk with the Response framework proposed by this report

Regarding AWWA Standards, Standard 651, *Disinfecting Water Mains*, has already benefited from the research and findings of this study. Project staff has shared findings with AWWA staff and volunteer committees and changes to the Standard are underway. The Technical Guidance Notes used in the United Kingdom already advocate a tiered risk-based approach; any revision of the Notes may want to consider the findings of this project as well.

Regarding water utility practices, the summary tables and Main Break Triage Flowchart developed in the report provide a basis for updating utility main break repair practices to more effectively address sanitation and customer issues. Four practices are described in detail to help operations and maintenance staff address the multitude of issues faced during a break and repair: monitoring disinfectant residuals, attaining scour flushing velocities, implementing slug disinfection, and maintaining positive pressure. To help field crews who are doing repairs to remember and implement good practices during repair of water main breaks, a Field Pocket Guide listing good practices was developed as part of this project. The Field Pocket Guide, titled, *Good Practices for Preventing Microbial Contamination of Water Mains*, may also be useful in utility training programs for crews involved in these activities.

Concerning regulatory agencies, the laboratory research conducted on disinfection and flushing provides a sound technical basis for public health protection and mitigation measures related to main breaks. The use of water pressure and presence or absence of contamination to trigger boil water advisories and notices will hopefully clarify the risk associated with the four types of main breaks and help regulators and utilities focus their efforts and manage customer notifications in the most efficient way possible.

PROJECT DELIVERABLES

All the project deliverables can be downloaded from the 4307 project page. Printed copies of the final report and Field Pocket Guide can be ordered as 4307a. Additionally, the Field Pocket Guide can be ordered separately as 4307b. The Appendices from the report are posted separately on the WRF Website. Lastly, a Fact Sheet was developed to highlight the key findings.

RESEARCH PARTNER

Drinking Water Inspectorate